# *The* TREND IN ENGINEERING

*at the University of Washington*

*In this issue:*


PLANNING A COMMUNITY-WIDE AIR-POLLUTION STUDY

VARIATION OF VHF FIELD STRENGTH BEYOND LINE-OF-SIGHT

NORTHWEST CONFERENCE ON ROAD BUILDING

SHEARING RESISTANCE OF BOLTS PARTIALLY EMBEDDED IN CONCRETE

COLOR SPECIFICATION



*April, 1954*

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THE ENGINEERING EXPERIMENT STATION

# Specialists, Scholars, and National Security

SEVERAL MEMBERS OF THE UNIVERSITY OF WASHINGTON FACULTY recently were asked to comment on the following statement appearing in an article bemoaning a trend in American universities:

America today is producing specialists, not scholars, but so long as national security must be placed above everything else, this will be inevitable.

From half-a-dozen replies quoted in **The Graduate School Review of the University of Washington,** for February, 1954, two divergent views are presented here.

SCHOLARS are often specialists and this specialization is still quite frequently in fields not directly related to the preservation of national security. I take it to mean that in the present emergency there are strong pressures toward the restriction of scholarly research to specialized inquiry into subjects in which its results will directly promote the nation's capacity to make war . . . So interpreted the statement seems to me mistaken on two counts. 1) knowledge that will best enhance our war-making powers cannot in the long run be gained in this way, and the present emergency promises to be a long one . . . 2) The national security we want to maintain is that way of life in which men are free to develop the best capacities of human nature. This way of life can be destroyed not only by external attack but by the atrophy of those powers of understanding and appreciation with which constructive scholarship is concerned in fields in which the usefulness of knowledge in the business of making war is not, and ought not to be, the measure of its value. The demand that this work be given up for the foreseeable future in the interest of "security" is an example of the kind of narrow mindedness or fanacticism which Santayana described as "redoubling your effort when you have forgotten your aim."

—*Professor Arthur E. Murphy,* Philosophy.

THE world of knowledge as it exists today in science is so extensive that the mastery of one field may take even the exceptional student almost beyond his productive years. Mastery of more than one field may produce an interesting individual but not a scholar who himself pushed back "the frontier of ignorance" to any great extent. The demands of the world at present on the individual in science force him to become a specialist even in the narrow confines of his own science if he is to be a productive scholar rather than a well informed dilettante. This is not to be blamed on national security as much as upon the changing world which makes the same demands without the scepter of war. Elimination of national security as the driving force will change the picture very little—national security only showed the way.

—*Professor Joseph E. Henderson,* Director, Applied Physics Laboratory.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgical, Ceramic Engineering
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. Results of major investigations are published in the form of bulletins and reports. Current research findings from the Station's fellowship projects, as well as accounts of its activities, appear in the quarterly journal, *The Trend in Engineering at the University of Washington*. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

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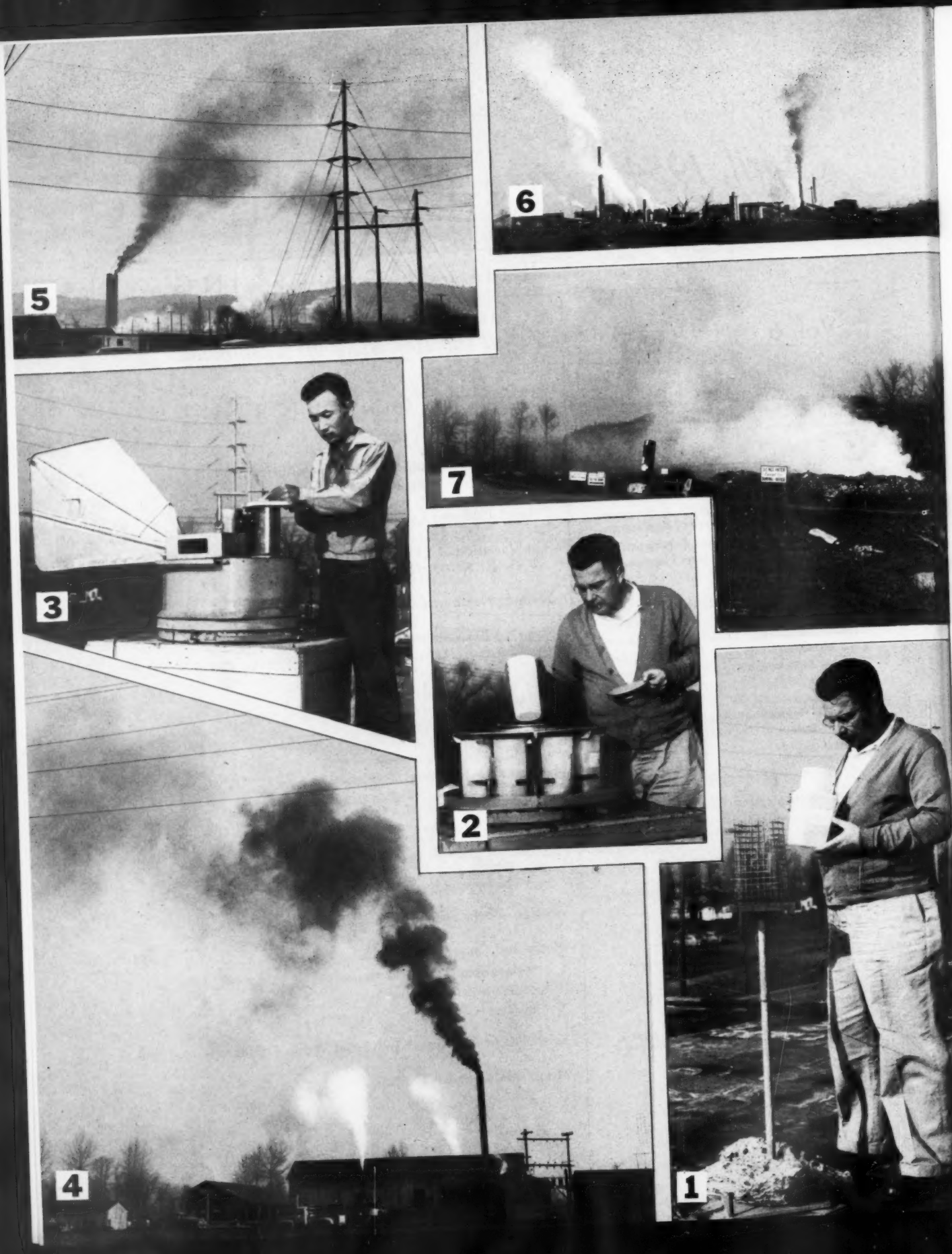
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# Planning a Community-Wide Air-Pollution Study

ROSS N. KUSIAN
*Director, Environmental Research Laboratory*

ARTHUR S. GORAI
*Industrial Hygiene Engineer*

CITY OFFICIALS OF LONGVIEW, WASHINGTON, a community of approximately 25,000, have been confronted in the last few years with an ever-increasing number of complaints about air pollution. Community groups, such as the Greater Kelso-Longview Community Council, have had air-pollution committees review the problem. Reports of the types of contaminants were varied and were consistent only in the numbers of complaints received. Everything from the neighbor's oil stove to one or more of the city's major industries was being blamed. In addition emotional stories in the popular press concerning smog and health aspects of air pollution tended to magnify the speculation concerning the extent of Longview's particular set of air-pollution problems.

The city officials consequently found themselves faced with demands that "there should be a law. . . ." But was a law needed? Would a law do any good? What had to be controlled? What standards should be specified?

Just as concerned were representatives of the major industries of the community. Some of the industries had been in operation since the city was planned and established in the early twenties. Why were they now being accused of being major contributors to a public nuisance?

In order to settle the problem for all concerned, Mr. R. S. Wertheimer, vice-president and resident manager of the Longview Fibre Company; Mr. O. G. Hittle, manager of P.U.D. No. 1, of Cowlitz County; Mr. H. E. Morgan, manager of the Lumber Division, Weyerhaeuser Timber Company; and Mr. R. E. Baker, manager of the Paper Division of the Weyerhaeuser Timber Company, offered to sponsor the Environmental Research Laboratory in a year-long study of the problem. A final report of the results of the project was to be turned over to the city. Longview's city council accepted this plan and the Laboratory was authorized to begin the project on September 23, 1953.

## Planning the Study

The innumerable publications which describe extensive studies, such as those in the Los Angeles and the Detroit-Windsor areas, say but little about the annual budgets of several hundred thousand dollars required to conduct such projects. Unfortunately, virtually no attention has been paid to the problem of offering technical assistance to the smaller cities. What, then, could the Laboratory staff members do for Longview with its available research funds approximately equal to four months' salary of the Los Angeles County Air Pollution Director? This comparison is not a reflection on the community of Longview, for, on the basis of cost per capita, Longview would undoubtedly far surpass Los Angeles. But in major studies with so-called "plush" budgets the importance of costs does not act constantly as the limiting factor in deciding whether to investigate interesting phases of the project. Air-borne dirt, deposited dirt, noxious gas concentrations, and many other items may be correlated with everything from the frequency of meteorological inversions to the number of automobiles passing a given intersection. However, in this project the question was: How could the staff of the Laboratory give the community of Longview the largest amount of usable data at the least possible cost?

On this basis the following plan of work was outlined:

1. Initial survey
   a) Note topography and possible sources of emission.
   b) Through interviews and inspections, investigate all phases of complaints.
   c) Determine possible locations of recording and sampling equipment.
2. Installation of equipment
   a) Set up approximately 12 non-directional and one directional dirt-fall collector, and train local man for servicing.

LEGEND: **View (1), Mr. Kusian with new type of plastic dirt-fall jar and stand; (2), MR. KUSIAN with directional dirt-fall collector showing the nine jars (for the eight points of the compass plus a calm jar); (3), MR. GORAI examines the dirt-fall collector with cover and vane attached; (4), (5), (6), (7), views of local sources of air pollutants in the Longview study.**

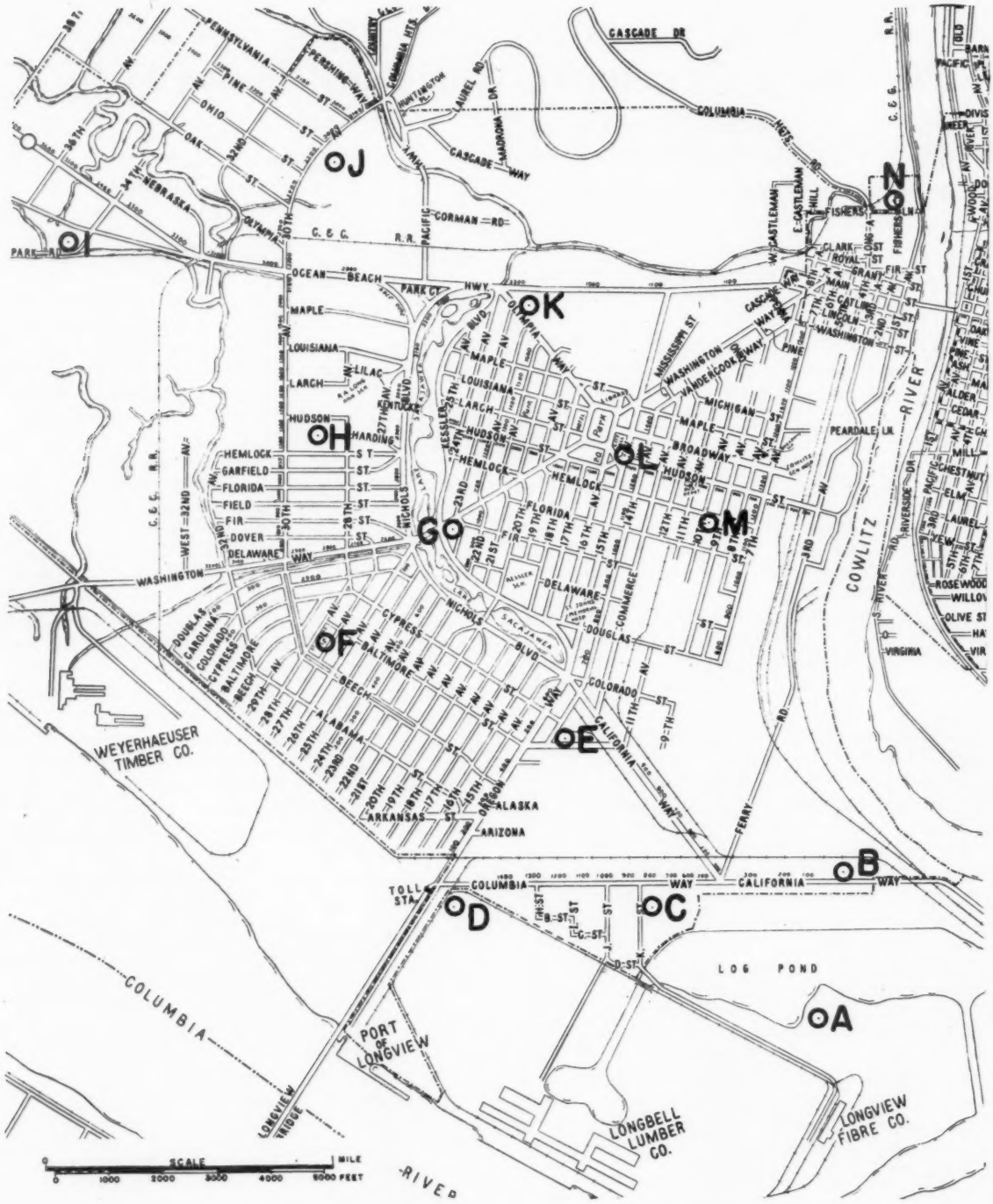


**FIG. 1. MAP SHOWING LOCATION OF THE DIRT-FALL STATIONS**
*Adapted from Pittmon Map by* Showalter and Underwood, Portland, Oregon, 1950

b) Arrange for obtaining allied meteorological information from nearby weather stations.

3. Measurement of dirt fall-out throughout the community
   a) Have local man check equipment weekly.
   b) Collect samples monthly and ship to the laboratory for analysis.
4. Measurement of emissions
   a) Sample stacks of major industrial plants for emission rates.
   b) Record visual indications of smoke by Ringlemann readings, photographs, and fly-paper-like panels in unusual cases.
   c) Collect random samples of gases, vapors and fumes in cases where evidence of contamination from such sources is apparent.

**Initial Survey**

Longview is situated on a level, delta-like point at the intersection of the Cowlitz and Columbia Rivers in Southwest Washington. It lies in a pocket-like valley with mountains almost entirely surrounding it. The eastern limits border a section of Kelso and the Cowlitz River. The northern and western limits extend into almost a mountainous area. An area of heavy industrial plants along the Columbia River is just outside of the southern limits. In the winter the prevailing winds come down the Columbia River from the southeast, while in the summer the prevailing winds come up the Columbia from the west.

The industrial area along the Columbia is composed of lumber mills, power plants, paper mills, port facilities, oil-storage areas, an aluminum reduction plant, and numerous commercial-type companies. There are, obviously, numerous contributors to air pollution in this area.

Along the Cowlitz River are several smaller industrial plants, both in Kelso and Longview, and a dump. The obvious sources of pollution in this area were the lumber mills and the dump. Since fuel oil is popular for heating, the residential areas offered no major contamination on casual inspection. However, some exceptions were noted in areas where many circulating heaters were in use. In the business district, an incinerator at a grocery was the cause of several complaints.

During the last part of September, 1953, staff members of the laboratory carried on a series of casual visits with businessmen, housewives, industrial leaders, civic officials, and workmen such as service station attendants, etc. They were asked if they thought there was an air-pollution problem; if so, what was it in particular they considered a problem; did air pollution affect their activities and properties either at home or at their place of work; and what did they think caused the difficulty.

Virtually unanimous in opinion were the housewives. They emphatically complained of having clothing soiled by an "oily soot" and, in some cases, by cinders. Second in order were complaints of excessive corrosion of automobile bodies and other metal parts. This corrosion was blamed on the paper mills. Of interest was one man's contention that gases from a paper mill were corroding the teeth of his stuffed cougar! Third, some complaints were made about the odors from the paper mills, although these were surprisingly few. Apparently the community in general accepts the stray odors as a necessary adjunct to the paper industry.

In summary then, the major problem was that of "oily soot" deposits. Source of this type of contaminant was not apparent in the initial survey.

**Dirt-fall Collection**

These initial visits and survey indicated that determination of dirt-fall would be of assistance in analyzing the problem. The term "dirt-fall" is used to describe the particulate portion of the air pollutants which tend to fall out by gravity onto horizontal surfaces. If the suspended dust is sufficiently small, it tends to remain suspended in the air. Measurement of dirt-fall is generally done by use of the dirt-fall jars, while suspended dust is measured by continuous high-volume air samplers, electrostatic precipitators, and other devices.

The simple dirt-fall jar, which has been in use in various cities since 1912, is fairly well established as a basic measuring tool. One of its primary advantages is that numerical comparisons of different studies can be made, providing that the techniques used do not vary too widely.

The dirt-fall jar, as shown in view (1) of the frontispiece, is a modification of the type generally used, and is being used in Longview for the first time. This plastic container was designed in order to overcome the loss of samples because of freezing. Heretofore it was necessary either to add anti-freeze to the sample, which interfered with the analysis, or risk losing the glass jars as well as the sample. The hardware cloth not only discourages children from target practice with rocks, but also its sharp points make it highly uncomfortable for a bird to roost on the plastic containers.

Measurement of dirt-fall by means of dirt-fall jars consists of allowing particulate matter to settle into the jar where it is trapped by the shape of the container and the distilled water kept in the container.

On the basis of the initial survey the community was divided into a series of sections, which contained essentially either all residential, commercial, or industrial activities. Originally it was intended to establish a series of dirt-fall stations on arcs with

radii using Station N in Fig. 1 as the focal point. In this way the first series of stations would fall in a line almost paralleling the Columbia River. However, the following basic standards for station location forced modification of the original plan:

1. Stations should be as nearly uniform in height as possible.
2. They should be readily accessible for servicing.
3. They should not be accessible to children and the public in general. It is desirable to use civic buildings, schools, etc., as much as possible.
4. There should be no chimneys or possible sources of contaminants in the immediate vicinity.
5. In order to avoid contamination from leaves and obstructions of natural wind currents, no high trees or other obstructions should be in the vicinity.
6. Construction of the roof should be such that unusual air turbulence will not occur.
7. Consideration should be given to locating some of the stations in positions which would tend to isolate the major industrial sources merely by the location with respect to the prevailing winds.

With these considerations, 14 stations were selected and are marked as Stations A through N in Fig. 1.

An employee of one of the sponsoring companies checks the dirt-fall jars weekly, either to add water in case of evaporation, or to change containers in case of a heavy rainfall. He also collects the samples from each station monthly, seals them, and ships them to the laboratory for analysis.

In the laboratory the accumulation of leaves, bugs, and other extraneous matter is screened out. The pH is recorded, and the samples are evaporated to 100 ml. The sample is then filtered in order to obtain the insoluble solids. After being weighed, the insoluble portion is washed in carbon tetrachloride. The percentage of solids dissolved by the carbon tetrachloride is an indication of what fraction of the solids is from oily and tarry matter. The residue remaining after extraction is ignited, and the per cent loss of weight is recorded. These data give an indication of the amount of combustible solids. An aliquot of the original filtrate is then evaporated to dryness and these total soluble solids are then ignited in order to obtain the percentage of combustibles. Also analyses for sodium and sulfate content are run on other aliquots. In addition special tests on a random basis are planned for calcium and fluorides. The final report will include the following data:

1. Total solids in terms of tons per square mile per month
2. Total combustible solids in the same unit
3. Amount of carbon tetrachloride soluble solids
4. Amounts of sodium, sulfates, fluorides, calcium, etc.

The simple dirt-fall jar is limited in value since it collects the dirt without indicating from which direction it came. As a means of overcoming this limitation, the original proposal called for the installation of a directional dirt-fall collector at a central station located so that the various large industries formed an arc around it.

This instrument, two views of which appear as (2) and (3) of the frontispiece, was developed by the Battelle Memorial Institute. Essentially it consists of a series of dirt-fall jars representing the eight points of the compass and a calm jar, all so arranged that only one jar is open at any one time, and that one corresponding to the direction of the wind at the moment. Suitable controls are provided to shift the opening of the device to the calm jar when the wind drops below an arbitrary minimum of 3 miles per hour. Thus the data, from a single station, after being analyzed in the manner outlined above, can be broken down into eight directions and a calm.

However, a serious limitation on such data is that they do not indicate the *rate* of dirt-fall from each direction. As an example, a certain wind direction might be infrequent, but if dirt-fall from this direction were exceedingly high from a heavy source of emission, that fact might not be revealed. Consequently a wind-hour meter (view 3) was installed immediately adjacent to the directional dirt-fall collector. This instrument records the amount of time the wind blows from each of the eight directions and the time that it is calm. In this way the rate of dirt-fall at a certain station can be recorded in a manner similar to the polar diagram shown in Fig. 2.

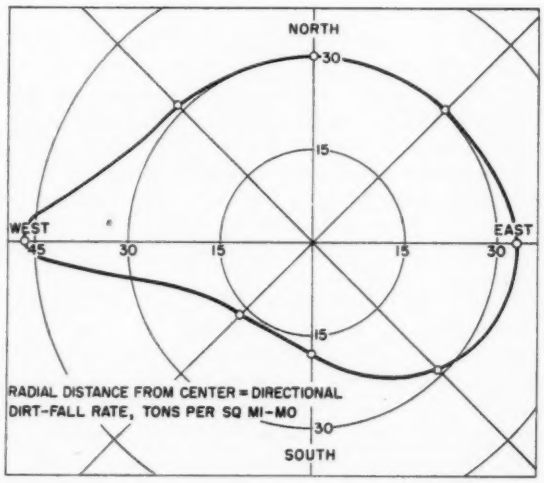


**FIG. 2. TYPICAL POLAR DIAGRAM OF COMBINED DATA FROM DIRT-FALL COLLECTOR AND WIND-HOUR METER**

*Adapted from* Engdahl, Fig. 2, *AIR REPAIR*, Vol. 3, No. 1.

In the initial discussion with officials in Longview, the ideal location for the directional collector appeared to be near Station E. However, after the initial survey, the fact that numerous small lumber-mills between Station E and the larger industries would also be contributors and thus complicate isolation of sources, forced these plans to be revised.

After the initial survey was completed, it was decided to move the directional collector from station to station at three- and four-month intervals. Factors to be considered in locating the directional collector were the angle between the plants (which should be a minimum of 40°) and the prevailing winds.

In November, 1953, when the directional equipment was put into operation, Station C was selected. Data from this point would tend to isolate the contributions of the Longview Fibre Company and of the Cowlitz County P.U.D. power plant which is located within the yards of the Long-Bell Lumber Company, from the numerous smaller plants which lie to the north, east, and west of Station C.

Later Station D will be used so as to isolate the Cowlitz County P.U.D. plant from the small mills and Longview Fibre. During the summer months when the wind is from the west either Station F, G, or H will be used for another directional station.

Atmospheric samples will be taken for any special conditions that are found or reported.

**Stack Sampling**

In order to correlate the dirt-fall data, the major industrial stacks in the Longview area will be sampled. This is to be done only on a voluntary access basis. To date every plant manager interviewed has offered to cooperate in this study. This phase of the project is not yet underway, because it was considered desirable first to establish the dirt-fall collection procedures, and then, after that work became more or less routine, to start stack sampling.

During this interval the laboratory's sampling equipment is being completely modernized so as to incorporate the findings of the many research engineers who have been conducting extensive studies of stack sampling techniques in other areas. This equipment is now nearing completion, and complete reports will be made on it later.

**Interpretation of Data**

The correlated data of these planned studies should show the local and seasonal variations of air-pollution levels. Also it should pin-point the specific sources of the existing air pollution. In addition, comparisons can be made with other cities where similar studies have been made. Data are available for cities such as Seattle, Los Angeles, Cincinnati, Rochester, Chicago, Detroit, London, Liverpool, and Leningrad.

Because of the seasonal aspects of the study, no preliminary data are to be released. Actually, because of seasonal variations, conclusions from a single year's data may be somewhat doubtful. Results of long-term studies, however, indicate trends which should enable a community to evaluate its air-pollution problems in a far more intelligent manner, and to solve them more successfully.

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# Belgian Professor Lectures on Prestressed Concrete

Professor Gustav Magnel of the University of Ghent, Belgium, described the advantages of prestressed concrete construction in a lecture given February 12, at the Health Sciences Auditorium, before some 250 engineering faculty members, students, and professional engineers. Professor Magnel, who has designed notable prestressed concrete structures abroad, declared that the slow progress of this type of construction in the United States is chiefly due to the "soupy" concrete with high slump and low strength used by contractors here in their desire to save labor costs. The no-slump concrete used in Belgium for prestressed concrete, while requiring more labor than ordinary reinforced concrete, may not be more costly in the long run, since it minimizes rejects and repair. Production of good no-slump concrete would require shifting from the horizontal-axis type of mixer now in general use in this country, to the vertical-axis type.

Prestressed concrete requires only 20 per cent of the amount of steel and 50 per cent of the amount of concrete required for reinforced steel construction and is more fire-resistant than reinforced concrete.

Professor Magnel recommended that, as a beginning, requirements for some items, such as unit stresses and properties of materials, could be introduced into present building codes, before developing full specifications.

Professor Magnel, on completing a lecture tour of the United States and Canada, summarized his observations at a meeting of the Concrete Industry Board in New York City.

In a letter to Professor Farquharson after his return to Ghent, the distinguished Belgian makes the following statement: "May I thank you . . . for . . . the trip to Tacoma where I saw for the first time in the U. S. prestressed work executed in the greatest perfection."

# AN INVESTIGATION OF THE VARIATION OF VHF FIELD STRENGTH BEYOND LINE-OF-SIGHT*

G. H. KEITEL
*General Electric Gerald Swope Fellow*

H. M. SWARM
*Assistant Professor of Electrical Engineering*

G. H. Keitel

The field strength due to a VHF transmitter well beyond line-of-sight varies with time in an extremely complex manner. For fixed transmitter and receiver locations and a definite path, the received signal varies from instant to instant, exhibiting diurnal, weekly, and seasonal components of variation in addition to the more or less rapid fading. One of the most important causes of this variation is the changing gradient of the index of refraction in the troposphere.

The effect of the changing gradient has been examined by many researchers. It has been investigated from the standpoint of the correlation between the index of refraction gradient and the received field strength at the time the gradient is known. Except for special tests, very little is known about the troposphere on a continuous base, the usual data consisting of radiosonde ascents made twice daily. Although limited to this extent, much theoretical work is being done to bring the predicted field strengths into closer agreement with the experimental values.

The purpose of this paper is the study of field-strength variations from a different aspect, that of hourly variations, and their correlation with the variation of the index of refraction at the earth's surface. Radiosonde data taken concurrently provided a means of relating the atmospheric structure to the correlation coefficient obtained. The field-strength data were obtained on the 149-mile path from Portland, Oregon, to Seattle, Washington, on a frequency of 101.1 Mc. A similar study was made by Pickard and Stetson on the East Coast on a slightly different basis.[1] They checked the correlation between daily and weekly averages of field strength and index of refraction at the ground level. This type of correlation also was tried for the path under consideration.

## Theoretical Considerations

It has been shown that, by using mode theory, the field strength for various refractive index gradients can be predicted and that, as the index of refraction gradient increases negatively, a greater signal may be expected.[2]

H. M. Swarm

If a point on the curve of index-of-refraction versus height remains fixed with time and the curve remains straight, any fluctuation in the slope of the curve will be manifested in a change in the index of refraction at the ground level, $N_0$. Thus, an increase in the index at the ground should be accompanied by an increase in the field strength. For example, if the index of refraction at a height of 10,000 ft remains fixed, the change in predicted field strength in decibels is almost directly proportional to the change in the index at the ground level, as shown in Fig. 1. The signal predicted by this method is on the average 11 db below the actual received signal for this particular path. Most important in the present study is the direction of the line.

## Experimental Work

The field strength data used in this investigation were obtained from recording equipment operated by the University of Washington under contract with the National Bureau of Standards. The transmission path is from Portland, Oregon, to Seattle, Washington, 149 miles. The transmitter, the commercial FM

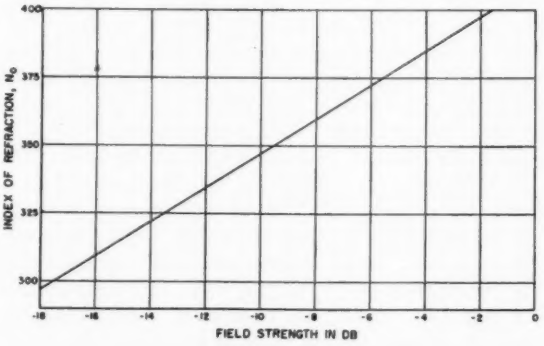


FIG. 1. RELATION OF PREDICTED FIELD STRENGTH TO INDEX OF REFRACTION AT GROUND LEVEL

* The experimental work for this study was done under N.B.C. Contract CST-481 with the University.

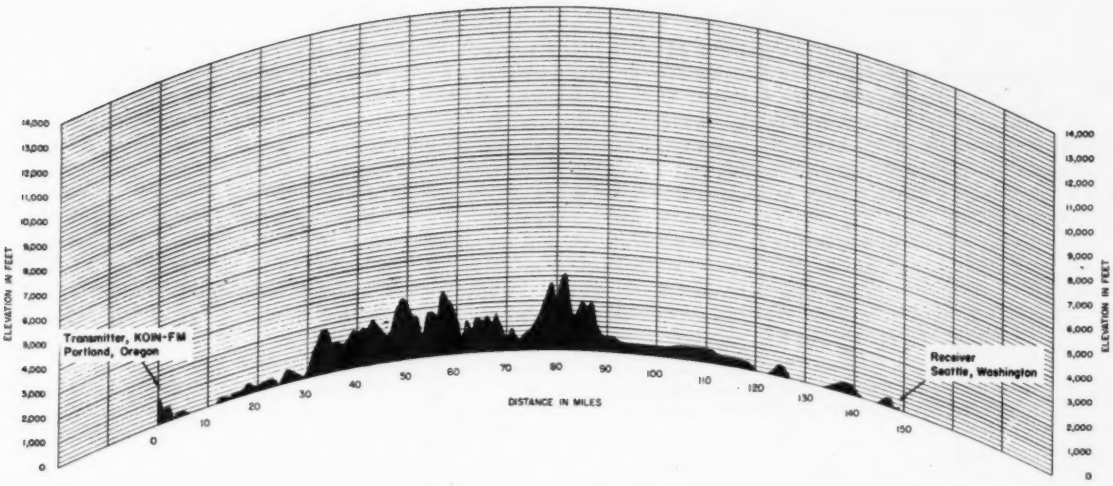


FIG. 2. PROFILE CHART
(Earth radius is 4/3, to correct for standard atmosphere diffraction.)

station, KOIN-FM, 101.1 Mc, has an effective radiated power of 39.3 kw in the direction of Seattle. The transmitting antenna is 1,600 ft above sea level and the receiving antenna at the University of Washington is 200 ft above sea level. A 3,000-ft ridge crosses the path near the midpoint, ruling out any possibility of line-of-sight propagation. The path profile is shown in Fig. 2.

For information on the atmospheric structure, data from radiosonde ascents were used. The Sand Point Naval Air Station in Seattle makes a radiosonde measurement every morning and evening at 7 o'clock, reporting the temperature, dewpoint, and pressure as functions of height. From these data, curves of the index of refraction, $n$, or more conveniently, $N=(n-1)\ 10^6$, versus height may be obtained from the well-known relationship,

$$N=(n-1)\ 10^6=\frac{77.6}{T}\left(p+\frac{4830e}{T}\right),$$

where

$T$ = air temperature in °K (°C+273),
$p$ = pressure in millibars,
$e$ = vapor pressure in millibars.

This formula uses the empirical constants obtained by E. K. Smith, Jr.[3]

Surface data at three points along the propagation path were obtained from the U. S. Weather Bureau. These points are the weather stations at the Seattle-Tacoma Airport, about 18 miles south of the receiver, the Portland Airport, about 9 miles northeast of the transmitter, and the Toledo, Washington, Airport, about 64 miles north of Portland and just to

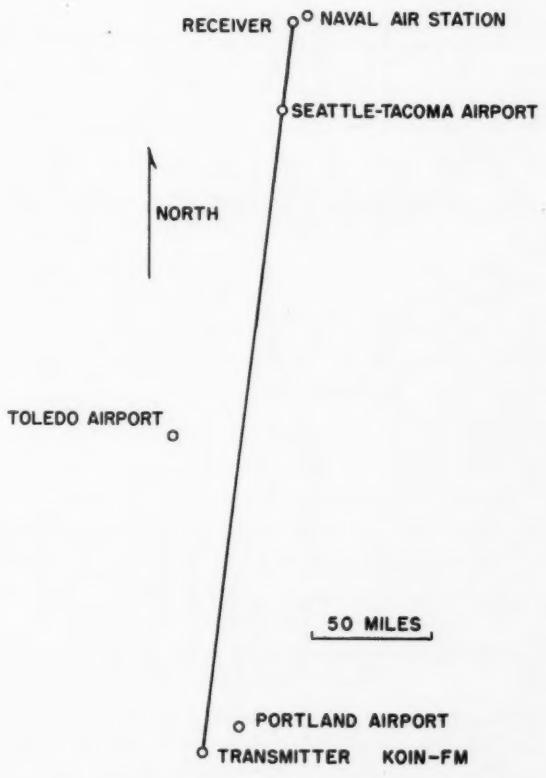


FIG. 3. LOCATION OF THREE STATIONS USED FOR SURFACE DATA

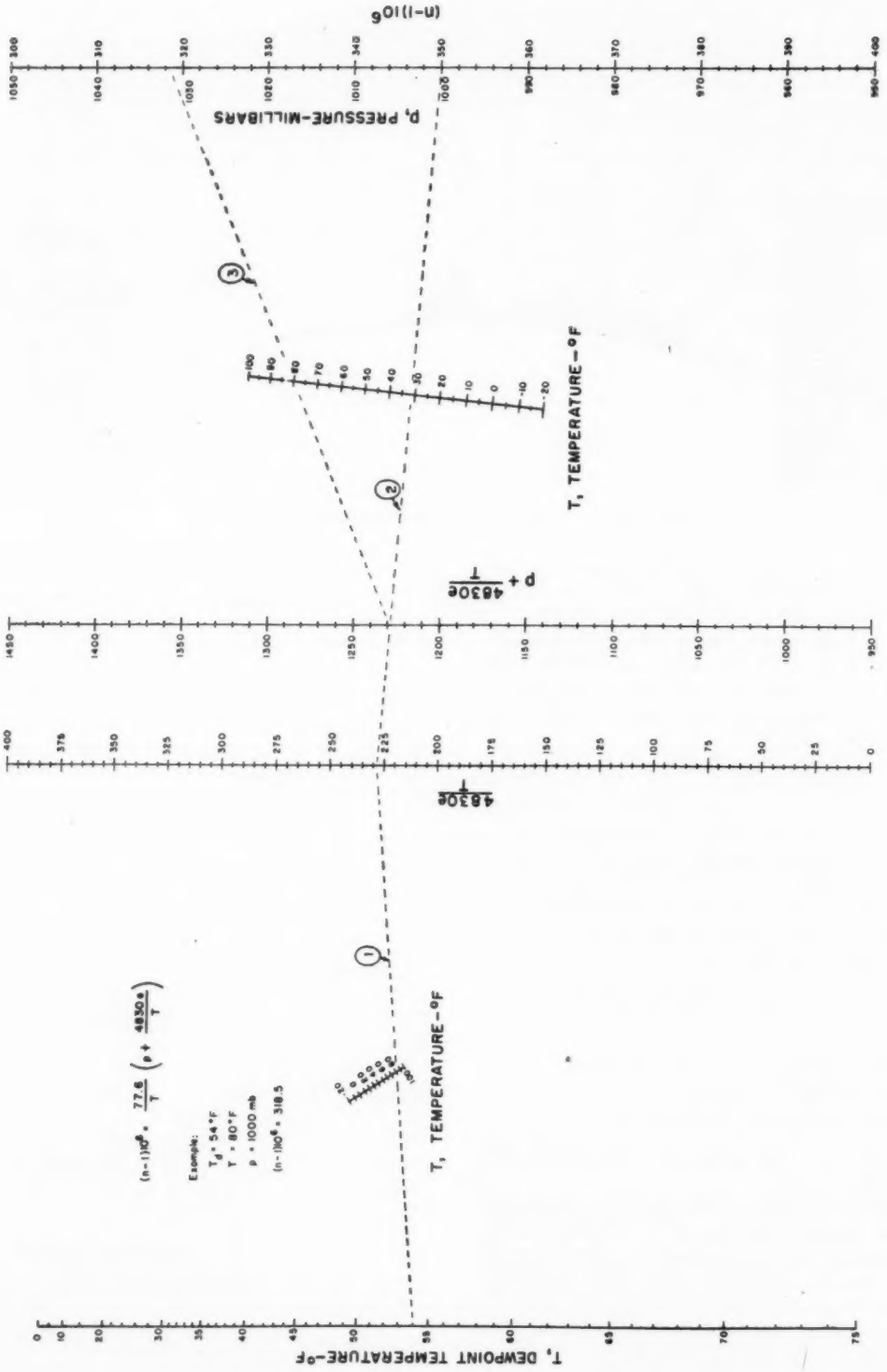


FIG. 4. NOMOGRAPH FOR DETERMINING THE INDEX OF REFRACTION OF THE ATMOSPHERE

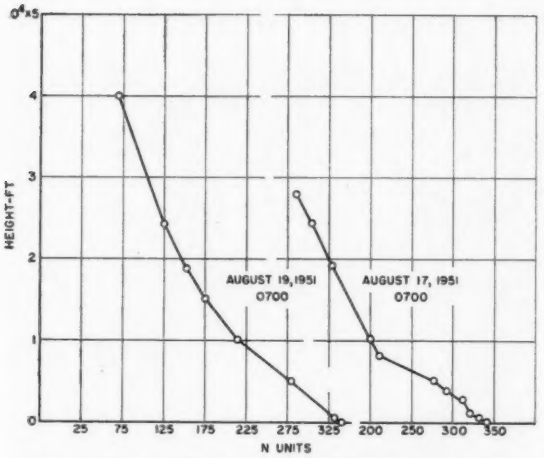


FIG. 5. TYPICAL GOOD AND POOR RADIOSONDE CURVES

the west of the midpoint of the path. The locations of these stations are shown in Fig. 3. The index of refraction at the ground level varies a considerable amount, depending upon the meteorological conditions of the area. Temperature, dewpoint, and pressure data taken every hour permit the calculation of the index at hourly intervals throughout the entire day. To facilitate the calculation of some 5,000 values of $N_0$, an expanded version of the nomograph described in a previous paper,[2] was used, and is shown in Fig. 4.

Data used in this study were taken during the period from July 8, 1951, to February 28, 1952. Only field-strength data for days on which radiosonde reports were plotted were used since it was desired to know the relationship between the degree of correlation of $N_0$ and field strength and the type of atmospheric structure present. Some field-strength data had to be excluded because of uncertainty of equipment calibration, local interference; and other local effects. Some data had to be discarded because of a highly variable noise level at the receiver.

Atmospheric structures were divided into three classifications, according to the radiosonde curve: good, medium, and poor. This division was made on the basis of the smoothness of the curve, the good curve having no breaks except for an almost always present break between 10,000 and 20,000 feet, and the poor curve having many very distinct breaks. The medium classification took in all of the remaining cases. Typical good and poor radiosonde curves are shown in Fig. 5, the good curve at the left. Curves of the hourly variation of $N_0$ at Seattle-Tacoma, Toledo, and Portland, and the field strength are shown for three typical days in Figs. 6, 7, and 8. For purposes of clarity, the curve of $N_0$ for Seattle-Tacoma is displaced down 10 units and the Portland

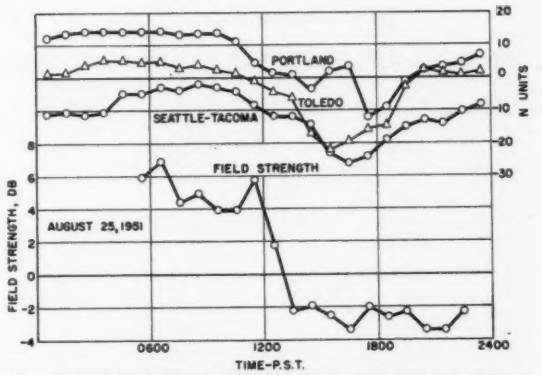


FIG. 6. CORRELATION OF INDEX OF REFRACTION AND FIELD STRENGTH, AUGUST 25, 1951

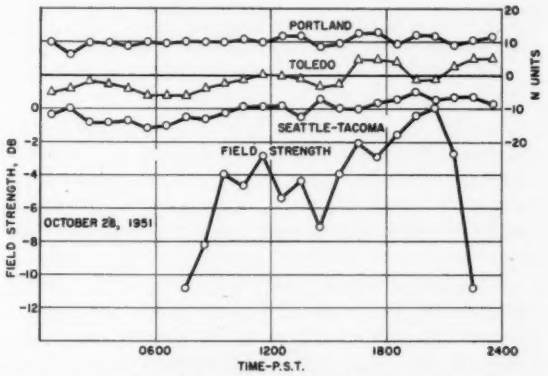


FIG. 7. CORRELATION OF INDEX OF REFRACTION AND FIELD STRENGTH, OCTOBER 28, 1951

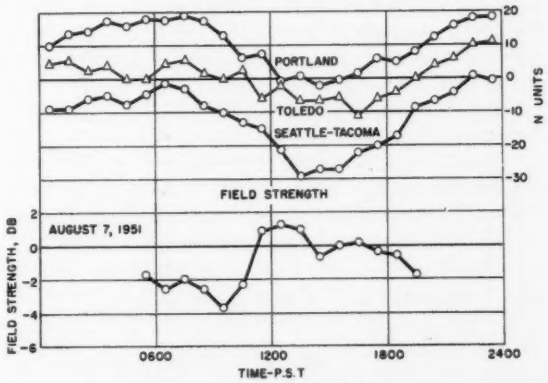


FIG. 8. CORRELATION OF INDEX OF REFRACTION AND FIELD STRENGTH, AUGUST 7, 1951

curve, up 10 units from their true positions with respect to the Toledo curve. For the best correlation, all four curves should run approximately parallel. In Fig. 6, the correlation is quite good, in Fig. 7, negligible, and in Fig. 8, negative.

**TABLE I**

| Type of Data | Seattle-Tacoma | Toledo | Portland |
|---|---|---|---|
| All Data..... | (735) 0.235 | (672) 0.076 | (735) 0.290 |
| Good Radiosonde Group..... | (269) 0.245 | (226) 0.362 | (269) 0.247 |
| Medium Radiosonde Group..... | (126) 0.443 | (110) 0.613 | (126) 0.343 |
| Poor Radiosonde Group..... | (340) 0.299 | (336) 0.415 | (340) 0.395 |

**Correlation**

Correlation between the field strength and the refractive index at the ground was computed for all the data from each station (Seattle-Tacoma, Toledo, and Portland), and then separately for good, medium, and poor radiosonde curves. The radiosonde curve was assumed to exist for 6 hours preceding and 6 hours following the radiosonde measurement. The correlation coefficients obtained are shown in Table I, with the number of hours of data used in computing each coefficient in parentheses.

It might be noted that the small number of hours in some groups could easily give rise to the high correlation found. Moreover, the highest correlation coefficients were obtained for the groups where the lowest correlation was expected. It is doubtful that larger samples of data will give much better correlation, because of several of the following effects which were ignored in the original assumptions:

First, the fixed point at great altitudes may not remain fixed. In the 178 radiosonde curves examined, the day-to-day variation in the curve at great heights is small, amounting to 5 to 10 *N* units over a period of several days. Though small, this variation may be quite effective in changing the signal level, thus introducing a third variable and lowering the correlation. If the variation in the index at some height is deducted from the ground variation, a much higher correlation coefficient could be expected.

Second, the atmosphere is assumed to be stratified for the whole path. True, the weather conditions tend to be very much the same all along this path for most of the time; however, the stratification may not be perfect, or it may not exist at all, resulting in different atmospheric structures at different points along the path. Not much can be said with regard to predicting field strength in a non-stratified atmosphere, and no one surface point could be expect to correlate well with the field-strength variation.

Third, the break height in the bi-linear atmospheric structure may vary while the slopes of the curve remain the same. Thus an increasing height would result in an increasing index at the ground. The effect of the varying break height has not been studied for the heights involved here, but an increasing height is believed to cause an increased signal.

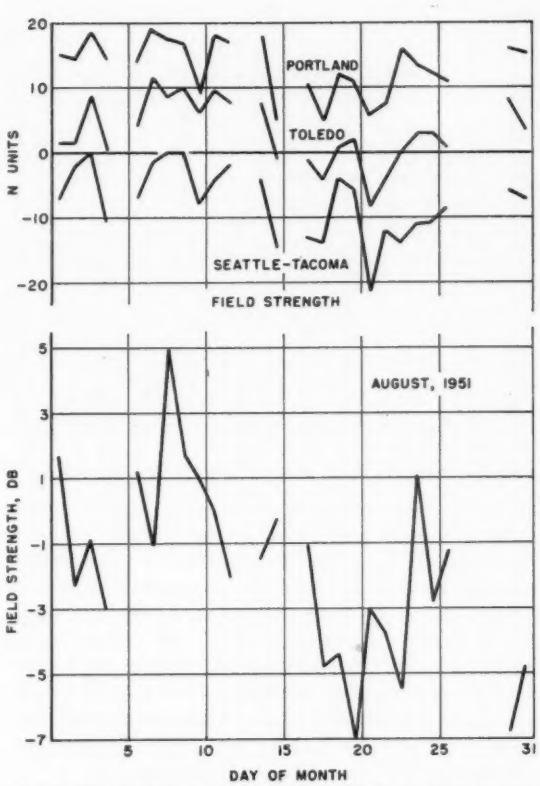


FIG. 9. CORRELATION OF AVERAGE INDEX OF REFRACTION AND FIELD STRENGTH FOR AUGUST, 1951

And fourth, the assumption that, as the index at the ground changes, this change will be distributed all the way up the curve, is very doubtful. The variation at the ground may extend up only a few hundred feet, or it may progress to increasing heights as time passes.

The possibility that the atmospheric structure progressively changes from one end of the path to the other should show up by an increased correlation between the field strength and index of refraction when one curve is shifted with respect to the other. This phase shift should also be related to the movement of air masses. This has been tried in a few cases, but with no conclusive results. It would be expected that the shift would be obvious in the curves of the index of refraction for the three stations. In all the cases examined, the diurnal variation of the index obscured any progressive variation.

As a matter of interest, the correlation between the average field strength from 6 P.M. to 12 P.M. and the index of refraction during the following morning was calculated in an attempt to duplicate Pickard and Stetson's results.[4] The correlation coefficients

*(Continued on page 32)*

# Seventh Northwest Conference on Road Building

*Left to right:* **University President HENRY SCHMITZ; Washington Highway Director W. A. BUGGE; Oregon Highway Director R. H. BALDOCK; Engineering Experiment Station Director F. B. FARQUHARSON**

PRESIDENT HENRY SCHMITZ welcomed over three hundred visitors to the campus at the opening of the Seventh Northwest Road Conference in More Hall, February 17-19. This meeting, sponsored here by the Department of Civil Engineering, is held on alternate years at Oregon State College and the University of Washington. Registrants were well distributed among the various road-building organizations, as indicated by the following breakdown of affiliation: state highways, 26%; county roads, 26%; industry, 20%; city streets, 13%; federal agencies, 5;% education and publishing, 4%; consulting engineers, 3%; contractors, 3%.

While the great majority of the registrants came from Washington, 9 per cent were from Oregon and 3 per cent from California. Alaska, New York, Massachusetts, District of Columbia, and Canada were also represented.

At the Wednesday morning session the chief highway problems in Oregon and Washington were reviewed by the highway administrators of the two states. Mr. R. H. Baldock, of Oregon, told of the new expressways under construction between Portland and Salem, and east of Portland, between Fairview and Burnside Bridge. The benefits derived from the improvement of such main highways far outweigh the costs. Mr. Baldock believes that these advantages can be obtained without the inefficiency resulting from the imposition of tolls. Mr. W. A. Bugge pointed out that highway expenditures in Washington since the war are far in excess of the entire highway investment of the State up to that time. With the expanding economy of the State, the

*Left to right:* **O. E. STONE and R. A. MOISIO, members of the Washington State Highway Commission; R. G. HENNES, Professor of Civil Engineering, University of Washington; FRED C. REDMON, chairman of the State Highway Commission**

costs of highway transport can be kept to a minimum only by maintaining a high rate of expenditure for road maintenance and improvement. It is important to determine the relative responsibility for road costs which should be borne by the various users and other beneficiaries.

The Wednesday afternoon session was devoted to highway research. Mr. G. A. Riedesel, of Washington State College, reported progress on the study of an equitable distribution of gas tax receipts among the several counties. Mr. Fred G. Redmon, chairman of the Washington Highway Commission, described the current study of future highway needs in the state. Professor R. G. Hennes, University of Washington, discussed the investigations in progress for the Legislature's Joint Fact-Finding Committee on Highways, Streets, and Bridges, and especially the study of the proper allocation of highway costs under the auspices of the Washington State Council for Highway Research. The role of engineering schools in furthering highway progress was discussed by Mr. Bob Glenn of the Institute of Transportation and Traffic Engineering at the University of California.

The use of airphotos in highway engineering was described by Mr. R. H. Kenyon, Engineer of Plans and Contracts for the Washington Highway Department, on Thursday morning. Mr. James H. McLerran of WSC then described the interpretation of airphotos to provide information on soil conditions. The problem raised by swelling subgrade soils was handled by Mr. Roger V. Le Clerc from the Materials Testing Laboratory of the Washington Highway Department. He showed how a balanced design of base

*(Continued on page 32)*

# SHEARING RESISTANCE OF BOLTS PARTIALLY EMBEDDED IN CONCRETE

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*Research Fellow, Engineering Experiment Station*

R. A. HECHTMAN
*Professor of Structural Research*

D. R. Young

Although information is available concerning the pull-out strength of steel bars and bolts partially embedded in concrete, the equally important problem of their resistance to shearing loads does not appear to have been investigated. Some data are available on the design of dowels in concrete pavement, but these were not considered applicable to the present problem. The space between two adjacent paving slabs allows a dowel a greater degree of freedom than exists in the case of the embedded bolt where the member, being fastened, bears directly on the concrete. Moreover, because the thickness of concrete pavement is much smaller than that in most building columns or beams, the possibility of diagonal tension failure in the former is more likely.

The research reported here was exploratory in nature and was designed to indicate the nature and the number of tests which would be necessary to obtain more adequate information on this subject. The effect of three factors upon the capacity of embedded bolts in shear was investigated: the ultimate strength of the concrete, the bolt diameter, and the length of embedment given the bolt. The test specimens, method of testing, and the test results will be presented hereafter.

### Test Specimens and Method of Testing

The proportions for the concrete mixes in this investigation are given in Table I. Builder's sand and gravel and Type I portland cement were used. The maximum size of aggregate was 1½ in. The slump of the mixes ranged from 4½ to 8 in.

Each test specimen was poured in three approximately equal layers. Each layer was rodded about one hundred times. Three 6-in. by 12-in. control cylinders were poured with each specimen. The specimens and control cylinders were removed from their forms after one day at room temperature, moist-cured at approximately 68° F for six days, and tested seven days after pouring. For a preliminary investigation of this type, the seven-day strength was deemed satisfactory in place of the usual 28-day strength.

R. A. Hechtman

Ordinary rough-forged mild-steel hex-head bolts were used. Their mechanical properties were not determined. They were free of rust and loose scale, but were not cleaned before embedment.

The test specimens, as shown in Fig. 1, were rectangular blocks of concrete with a bolt projecting from each end. After being capped with plaster of Paris, the specimen was placed between two heavy steel plates. The four large studs which clamped the two plates were used to apply a compressive stress equal to 0.2 $f'_c$ on two faces of the specimen. This stress simulated that existing in a reinforced concrete member under load. The average strength of the three control cylinders poured with each specimen was taken as $f'_c$. Each of the studs with its attached SR-4 strain gages was previously calibrated in a testing machine.

The shearing stress was applied to the bolts as shown in Figs. 2 and 3. The two bolts in each specimen were thus tested simultaneously, and the failure

**TABLE I**

**PROPORTIONS FOR CONCRETE MIXES**

| 7-Day Design Strength (psi) | Water-Cement Ratio (W/C) | Cement (lb) | Water (lb) | Sand (lb) | Gravel (lb) |
|---|---|---|---|---|---|
| 1500 | 0.71 | 11.6 | 8.24 | 37.9 | 58.0 |
| 2500 | 0.56 | 15.7 | 8.79 | 33.4 | 59.4 |
| 3750 | 0.45 | 20.5 | 9.22 | 29.9 | 59.0 |

* Mr. Young is now in the Structural Development department of the Boeing Airplane Company.

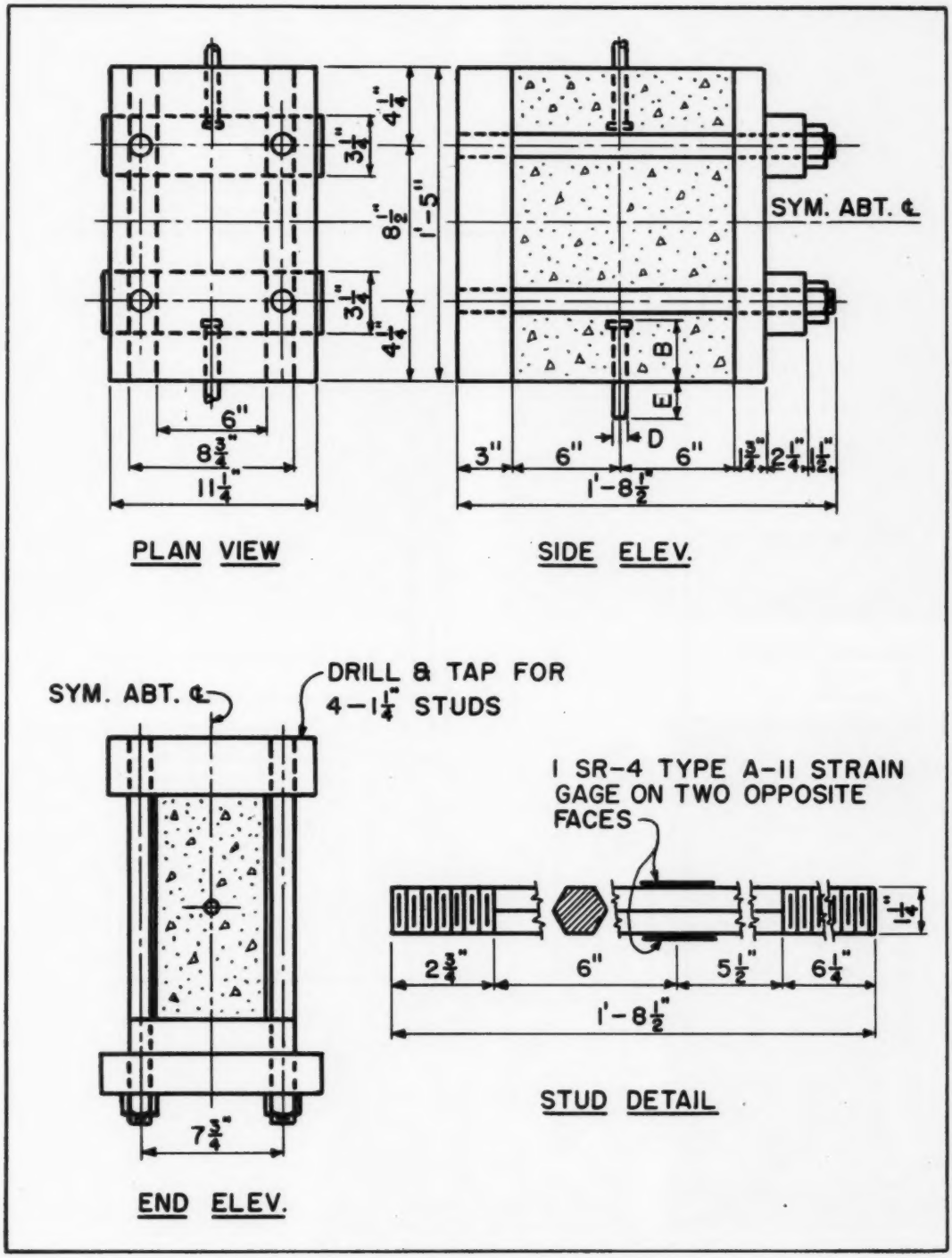


FIG. 1. DIAGRAM SHOWING TEST SPECIMEN AND EQUIPMENT FOR APPLYING COMPRESSIVE STRESS IN CONCRETE

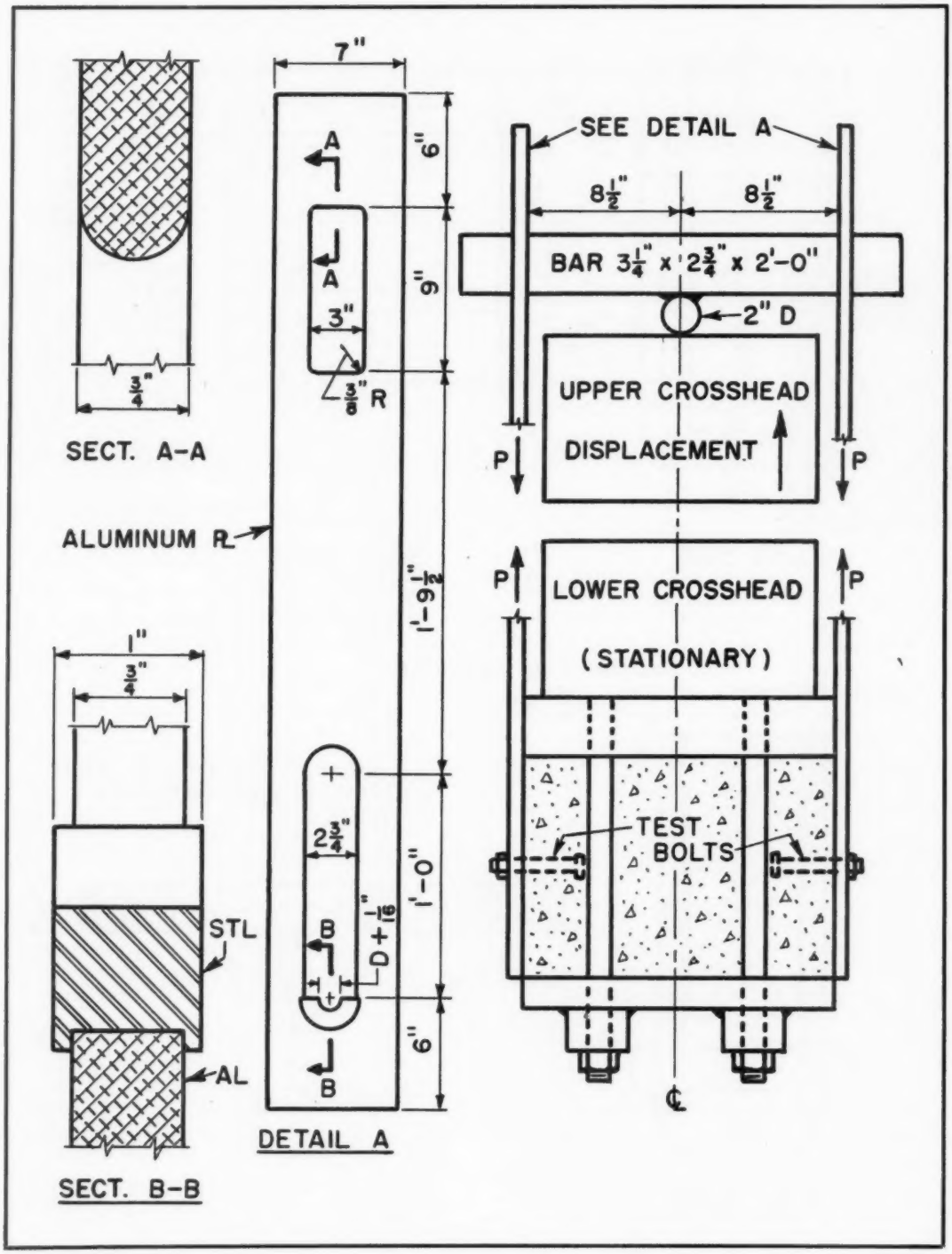


FIG. 2. DIAGRAM SHOWING DETAILS OF LOADING APPARATUS AND ARRANGEMENT OF SPECIMEN IN TESTING MACHINE

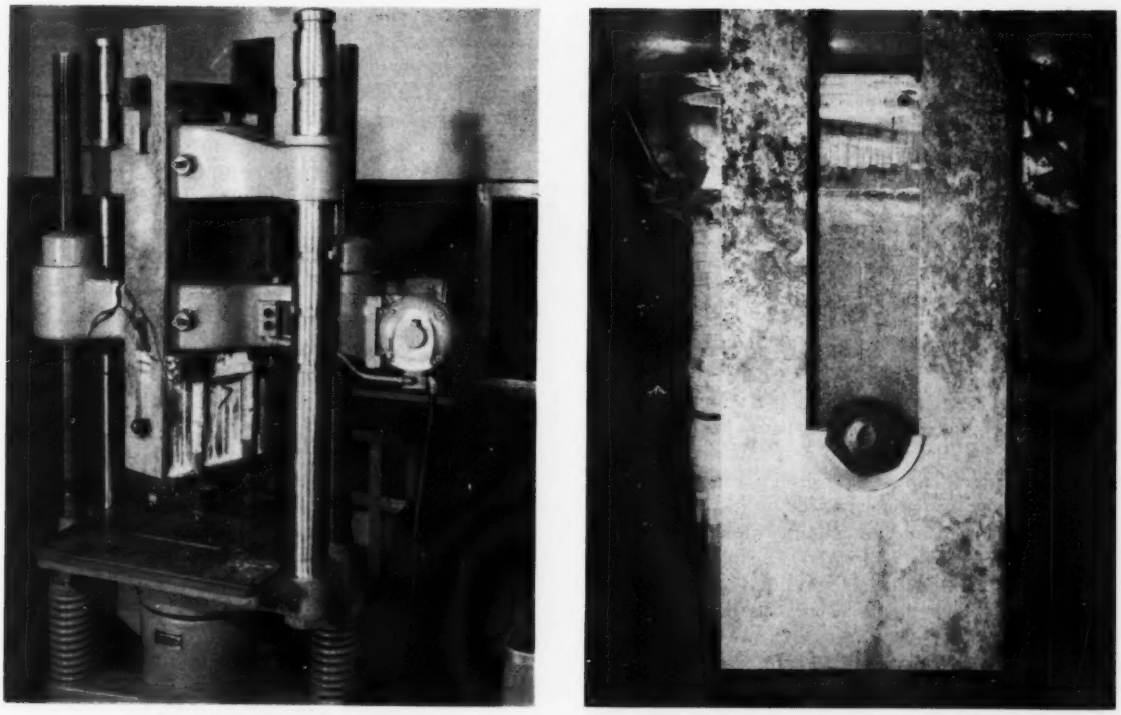

FIG. 3. METHOD OF TESTING: *Left,* SPECIMEN IN TESTING MACHINE; *Right,* METHOD OF APPLYING LOAD TO BOLT

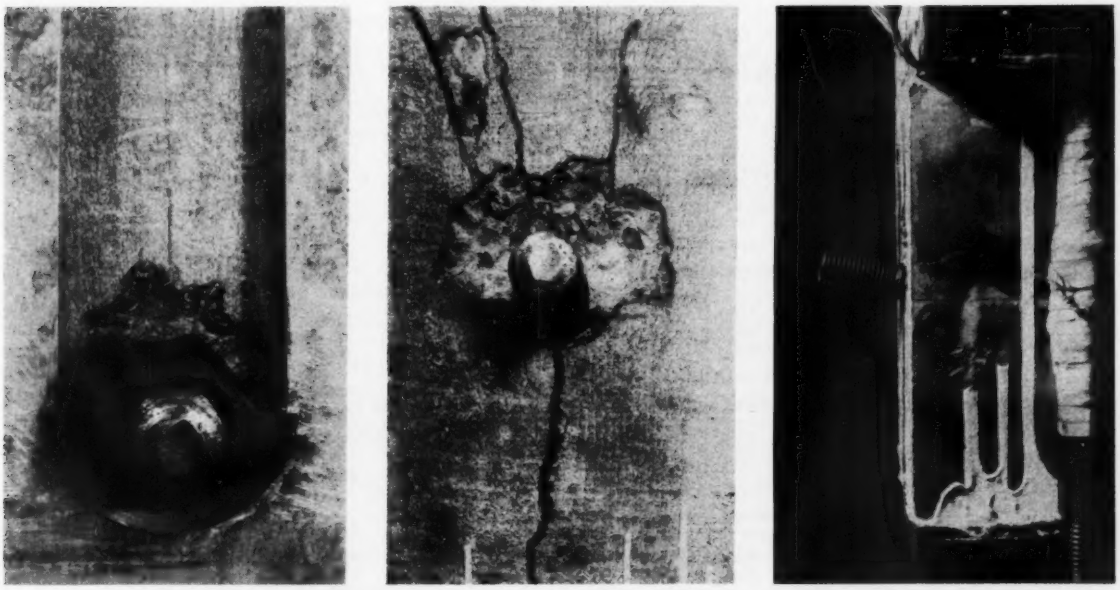

FIG. 4. MANNER OF FAILURE OF SPECIMEN NO. 7: *Left,* FIRST SPALLING OF CONCRETE AT LOAD OF 15,000 LB; *Center and Right,* APPEARANCE AFTER FAILURE

load of the weaker bolt was taken as the ultimate capacity of the specimen. After the weaker bolt had failed, it was not possible to continue the test to find the strength of the stronger bolt. During the test the load was applied in increments and the condition of the concrete surrounding the bolts was carefully observed for cracks and spalling.

**Results of Tests**

A summary of the properties of the specimens and the results of the tests is given in Table II.

Figure 4 shows the failure of a typical specimen. As the shearing load was applied to the bolt, a load was reached at which cracks began to form in the concrete adjacent to the bolt where compression stress in the concrete was developed. This initiation of failure is shown in the left-hand photograph in Fig. 4. As the shearing load was further increased, spalling occurred in this region. Finally, failure occurred by excessive spalling or by the bolt tending to split the block of concrete as the ultimate load was reached. The middle and right-hand photographs in Fig. 4 show this particular specimen after complete failure. The cracks have been marked with heavy black pencil.

The ratio of the load at the first visible crack in the concrete to the ultimate load ranged from 13 to 92 per cent according to Table II. However, difficulty in detecting the first crack probably accounts for part of this variation. The value quoted in this table is that for the end of the specimen which showed the first crack. This end was not always the one which ultimately failed.

Some of the data in Table II are plotted in Figs. 5, 6, and 7. The effect of the length of embedment upon the shearing resistance of ¾-in. diameter bolts is shown in Fig. 5. Increasing the embedment from 2.85 to 7.00 in. or from three to more than nine bolt diameters increased the ultimate load from 7.25 to only 8.00 kips.

TABLE II

SUMMARY OF TEST DATA

| Spec. No. | Bolt Dia. (In.) | Embedment* (In.) | Embedment Ratio | 7-Day Concrete Strength (psi) | Shearing Load on One Bolt† | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1st Crack (lb) | Max. (lb) | 1st Crack Max. % |
| **Effect of Bolt Diameter upon Shearing Resistance** | | | | | | | |
| 1 | 1⅛ | 4.25 | 3.78 | 2690 | 2500 | 13200 | 19 |
| 2 | ¾ | 2.85 | 3.78 | 2690 | 1000 | 7250 | 14 |
| 3 | ½ | 1.88 | 3.78 | 2485 | 1000 | 3320 | 30 |
| **Effect of Embedment Ratio upon Shearing Resistance** | | | | | | | |
| 2 | ¾ | 2.85 | 3.78 | 2690 | 1000 | 7250 | 14 |
| 5 | ¾ | 7.00 | 9.33 | 2415 | 1000 | 8000 | 13 |
| **Effect of Concrete Strength upon Shearing Resistance** | | | | | | | |
| 6 | 1⅛ | 4.25 | 3.78 | 1590 | 8000 | 8700 | 92 |
| 1 | 1⅛ | 4.25 | 3.78 | 2690 | 2500 | 13200 | 19 |
| 7 | 1⅛ | 4.25 | 3.78 | 3825 | 7500 | 15450 | 47 |

*Length of embedment includes thickness of head of bolt.
†Minimum value for two tests.

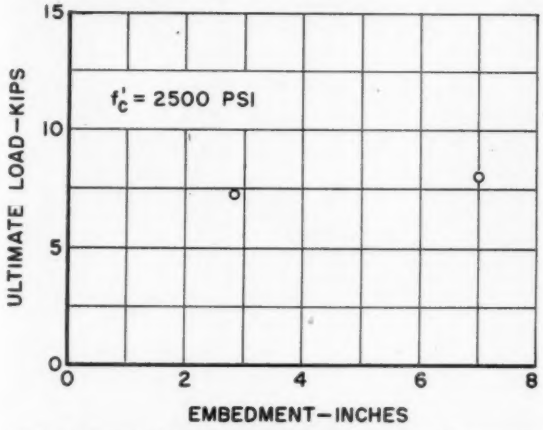


FIG. 5. EFFECT OF LENGTH OF EMBEDMENT UPON SHEARING RESISTANCE OF ¾-INCH BOLTS

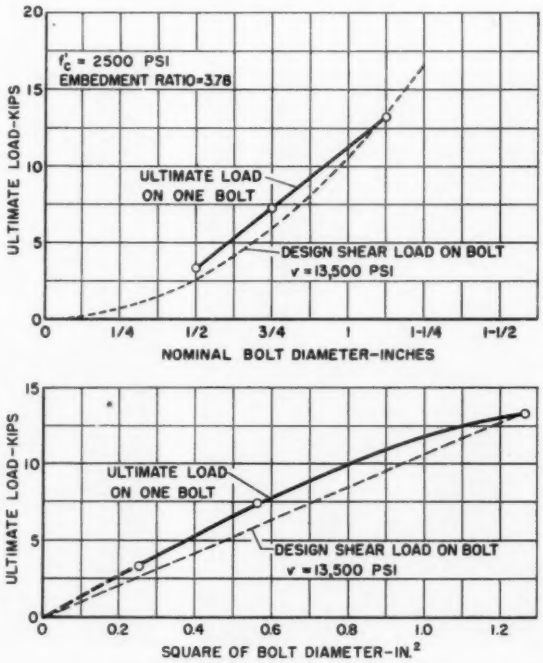


FIG. 6. EFFECT OF BOLT DIAMETER UPON SHEARING RESISTANCE OF BOLTS

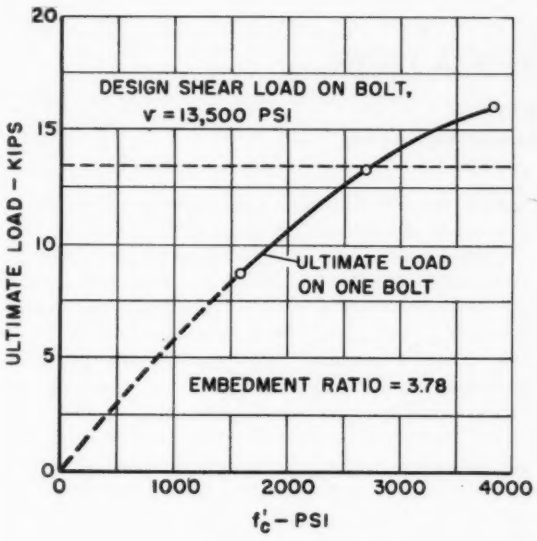


FIG. 7. EFFECTS OF CONCRETE STRENGTH UPON SHEARING RESISTANCE OF 1⅛-INCH BOLTS

Figure 6 indicates the effect of the bolt diameter upon the shearing resistance of the bolts under lateral loads, as well as the design load in shear on the bolt computed on the basis of the gross diameter. In the upper plot in this figure the former curve tends to parallel the latter curve, which is a parabola. Accordingly, since it has already been shown that the length of embedment was of little significance, the lower plot was made in terms of the square of the bolt diameter. This latter curve passes through the zero point but tends to fall below a straight line for bolt diameters greater than ¾ in. The probable explanation is that the shearing resistance of the bolts was proportional to the square of the diameter of the bolt so long as the bolt was not too close to the edge of the concrete in which it was embedded. This conclusion was supported by the observation that the specimens with 1⅛-in. bolts were split into fragments by the bolt, while those with smaller bolts were not. The edge distances of the ½-, ¾-, and 1⅛-in. bolts were 6, 4, and 2⅔ bolt diameters, respectively. The edge distance of the embedded bolt is apparently a factor that should be investigated in future tests.

The test results in Figs. 5 and 6 were found for specimens made from concrete with an approximate strength of 2,500 psi. The effect of three different concrete strengths upon the shearing resistance of bolts embedded in concrete is shown in Fig. 7. The shearing resistance increased less rapidly as the strength of the concrete increased. Also indicated in this figure is the design shear load for a 1⅛-in. bolt which was approximately equal to the ultimate capacity of the embedded bolt for a concrete strength of 2,500 psi. It is obvious that the design load for this particular embedded bolt should not exceed one-third to one-half of the design shear load permitted bolts in steel construction. More tests are required to establish more definitely the relation between the strength of the concrete and the allowable shear stress for embedded bolts.

**Summary and Conclusions**

The program of tests just described was exploratory in nature and preliminary to a more extensive investigation of the shearing capacity of bolts embedded in concrete. The general effect of the amount of embedment, the bolt diameter, and the concrete strength upon the shearing capacity of bolts embedded in concrete was found. Further tests are necessary to determine these relations more definitely. The importance of the edge distance of the bolt was also indicated, and this factor will be touched upon in future tests.

One factor which was not covered by this preliminary investigation was the effect of reinforcing steel in the vicinity of the bolt. The tendency of some of these plain concrete specimens to be split around the bolts suggests that properly placed reinforcement might substantially increase the shearing resistance of embedded bolts.

**ACKNOWLEDGMENTS**

**This investigation was carried out as a graduate research project in the Structural Research Laboratory of the Department of Civil Engineering, of which Professor R .B. Van Horn is head. Mr. W. R. Mason, formerly Assistant Professor of Civil Engineering, supervised the design of the concrete mixes.**

## TWO ENGINEERING AUTHORITIES TO GIVE WALKER-AMES LECTURES

Two prominent authorities in their respective fields are included in the Walker-Ames lectureships on the campus during the Spring Quarter. Dr. H. W. Liepmann, Professor of Aeronautics at the California Institute of Technology, will lecture on "Experimental Approaches" and "Modern Problems of Fluid Mechanics," May 10 to June 4, under the sponsorship of the Department of Aeronautical Engineering.

Dr. M. W. McLachlan of England, who has been visiting lecturer at the University of Illinois for the past two years, is sponsored by the Department of Electrical Engineering. His most recent book, just off the Cambridge Press, is *Complex Variable Theory and Transform Calculus*. His chief interest in electronics concerns loud speakers. Dates for his lectures have not yet been announced.

# COLOR SPECIFICATION

EDWARD E. MUELLER
*Assistant Professor of Ceramic Engineering*

E. E. Mueller

The usual method of specifying a color is to give it some identifying name. But, since the human eye is so sensitive that it can distinguish several million different colors, it is immediately apparent that such a procedure is impractical. In most cases no two observers will call the same color by the same name. For example, is chartreuse "greenish-yellow" or "yellowish-green?" Also, new color names are always appearing, especially in the fashion textile fields, which serve only to confuse matters further. A compilation of about 7,000 color chips with about 4,000 corresponding color names has been prepared by Maerz and Paul in their *Dictionary of Color,* alleviating the difficulty somewhat, but still leaving a great number unaccounted for.

Another method is to refer the color in question to some visually equivalent color standard. Several color systems are used for this purpose. In the Munsell system, color is specified in terms of hue, value, and chroma—hue being the general name of the color (red, blue, green, etc.), value being the degree of darkness or lightness, and chroma, the apparent intensity or saturation, or the departure of a hue from a gray of the same value. It is the basic concept of this system, i.e., that color is three-dimensional, which makes it invaluable to color visualization.

The Ostwald system utilizes a color mixture containing white, black, and a series of hues arranged systematically into a double-cone solid. According to the Ostwald designation, a color is specified by a number indicating the pure hue component and the relative amount of black and/or white contained.

Several other systems are also used in American commerce. Table 1 lists many of these systems with their principal and secondary uses and their principal defects.[1]

All systems utilizing a visual examination are subject to certain inherent errors. The major one is, of course, the human element. The brain, it must be remembered, contains no meters. The eye is a good comparator but a poor absolute instrument. For this reason the identification and memory of colors by eye is not satisfactory for many purposes.

Only by the expression in terms of physically determined quantities can an exact color specification be obtained. If color is to be measured, the quantities must, by nature, be psycho-physical. That is, they must be measured by physical means, yet interpreted in such a way that the results obtained correlate sensibly with visual estimates of the same color. Today the science of colorimetry offers an exact numerical method of specification in which a color is expressed in terms of three parameters which are unique for the given color and conform to visual conceptions and impressions. This method is used extensively by manufacturers of paints and varnishes, papers, plastics, textiles, and ceramics. With it definite numerical tolerances can be established by which to gage manufactured products.

**The CIE System**

The basis of this method is a series of international agreements commonly referred to as the CIE *(Commission Internationale de l'Eclairage*—International Commission on Illumination) system. Several standards were adopted by this organization in 1931 for international usage: the luminosity curve or sensitivity curve of the human eye, color-mixture curves for three imaginary standard lights, and energy-distribution curves for several illuminants.

Figure 1 shows the CIE Standard Observer, indicating the amounts of each of three primaries required to match a unit quantity of energy at each wavelength in the visual spectrum. This was developed by a statistical analysis of many human observers and offers a convenient method of computing the capacity of an observer to perform color matching. It will be noted that the curves have been adjusted so that (1) the values are all positive, (2) the $\bar{y}$ function duplicates the sensitivity of the human eye, and (3) the areas under the three curves are equal.

Recent experimental work has shown that some errors exist in the so-called Standard Observer, especially in the lower region of the spectrum, but these do not invalidate this method or most results obtained from using it.

Figure 2 shows the relative energy distribution of three CIE standard illuminants calculated from the Planck law with the constant $c_2$=14,380 micron-degrees. Curve A is the energy distribution of a

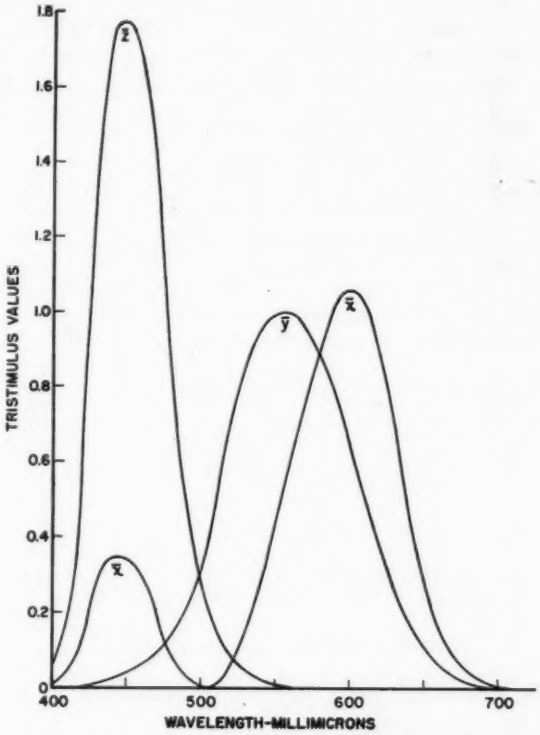


FIG. 1. TRISTIMULUS VALUES OF THE SPECTRUM COLORS

tungsten filament lamp operated at a color temperature of 2848° K. Curve B approximates mean noon sunlight, and is derived from the same lamp in combination with a two-cell Davis-Gibson liquid filter giving a color temperature of about 4870° K. Curve C is obtained similarly to give a color temperature of about 6740° K, and is representative of average daylight from a completely overcast sky.

With the use of these standards and a reflectance or transmission curve from a given sample, obtained spectrophotometrically, it is possible to calculate three values to explicitly define the sample. The relations used are:

$$X = \int_{380}^{760} ER\bar{x}d\lambda$$

$$Y = \int_{380}^{760} ER\bar{y}d\lambda$$

$$Z = \int_{380}^{760} ER\bar{z}d\lambda$$

where $X$, $Y$, and $Z$ are tristimulus values, $E$ is a function of the wavelength representing the energy distribution of the illuminant selected, $R$ is a function of the wavelength representing the reflection or transmission factor, and $\bar{x}$, $\bar{y}$, and $\bar{z}$ are the tristimulus

**TABLE I**

**APPLICATIONS AND PRINCIPAL DEFECTS OF SYSTEMATIC COLLECTIONS OF COLOR CHIPS USED IN AMERICAN COMMERCE**

| Color System | Principal Use | Secondary Use | Defects |
|---|---|---|---|
| Nu-Hue Custom Color | Sale of prescription-mixed paints | ..... | Restricted gamut in red-purple to blue hues |
| Colorizer | Sale of paint | Aid to color matching by customer | System rather complicated |
| Nu-Hue Color Coordinator | Aid to color matching by painter | Aid to color matching by customer | Non-uniform color spacing |
| Professional Color Guide | Aid to color matching | ..... | Too few colors |
| Plochere | Inexpensive color chips | Aid to color matching | Nonstandardization of paint components |
| Maerz & Paul | Definition of color names | Color specification | No light, saturated, or near-black colors |
| Villalobos | Color specification | Selection of harmonious colors | Small size of color chips |
| Ridgway | Color nomenclature | Color specification in biology | No near-black or near-white colors |
| *Color Harmony Manual* | Selection of harmonious colors | Color specification | Ostwald notation used not adapted to convenient interpolation or to easy visualization of color |
| Munsell | Color specification | Color education | Many of the strongest colors not shown |

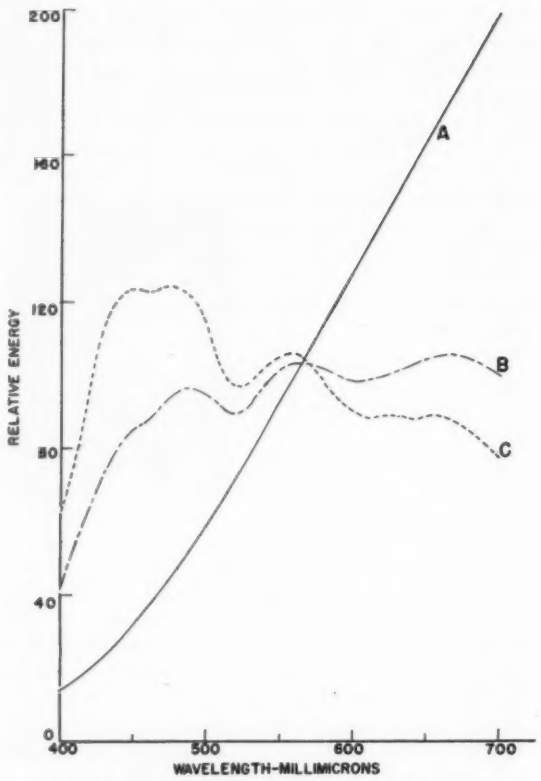


FIG. 2. ENERGY DISTRIBUTION OF CIE STANDARD ILLUMINANTS

values (distribution coefficients) of the spectrum colors.

The integrations are too complex to be obtained easily; hence they are usually approximated by obtaining the finite sums of

$$X = \sum ER\bar{x}\Delta\lambda$$
$$Y = \sum ER\bar{y}\Delta\lambda$$
$$Z = \sum ER\bar{z}\Delta\lambda$$

In most cases $\Delta\lambda$ is used with a constant value of 10 m$\mu$. For extreme accuracy, an increment of 1 m$\mu$ could be used but does not ordinarily justify the extra calculations incurred.

Having the tristimulus values, it is necessary to define new values, called trichromatic coefficients or trilinear coordinates, as follows:

$$x = \frac{X}{X+Y+Z}$$
$$y = \frac{Y}{X+Y+Z}$$
$$z = \frac{Z}{X+Y+Z}$$

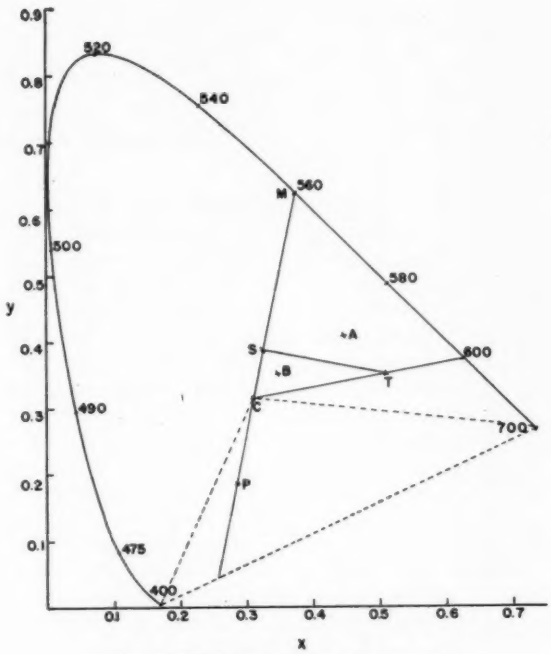


FIG. 3. CIE CHROMATICITY DIAGRAM

It will be noted that only two of these values are independent, since

$$z = 1-(x+y)\,,$$

regardless of the values of $X$, $Y$, and $Z$. Thus to specify the chromaticity of the sample, it is necessary only to use two trichromatic coefficients ($x$ and $y$ being generally selected).

It is then possible to plot the $x$, $y$ value of the color on a coordinate diagram, on which are also plotted the trichromatic coefficients of the spectrum colors which are obtained similarly. Figure 3 shows the coordinate plot, commonly referred to as the CIE chromaticity diagram. The horseshoe-shaped curve indicates the locus of the spectrum colors, with their respective wavelengths.

A chromaticity diagram such as this has one extremely important property in connection with the additive mixture of two or more colors. In Fig. 3 suppose that a certain yellow-red is located at point T, and a certain green is located at point S. Regardless of the proportions in which these two colors are mixed, the resultant color will always lie on the straight line connecting these two points. Thus, it is obvious that all real colors must lie within the area bounded by the solid line, since every real color can be considered to be a mixture of its spectral components in various proportions. Also, all real colors can be considered to be a mixture of the illuminant (white)

and spectral light of some definite wavelength. For example, the point S is shown to be a mixture of Illuminant C and spectrum light having a wavelength of 560 mμ, and the point T is shown to be a mixture of Illuminant C and spectrum light having a wavelength of 600 mμ. These wavelengths are known as the dominant wavelengths of the colors.

Since these colors lie on lines which terminate at a point representing a pure spectral color on one end and the illuminant on the other, the samples are evidently not as pure as the corresponding spectrum colors. The purity of the samples may be determined by measuring the relative distances of the sample point and the corresponding spectrum point from the illuminant point.

The portion of the diagram enclosed by the broken lines represents the purples and magentas. Thus, it is evident that purple cannot be obtained by mixing white light with a spectrum color. Rather, it must be obtained by some combination of red and blue. Therefore, to obtain the dominant wavelength and purity of a purple color, the complementary wavelength must be used. This always lies opposite the purple point on a line drawn through the illuminant. Thus, the complement of purple P is a green whose dominant wavelength is 560 mμ. The wavelength assigned to this purple is generally written as 560 (c) to distinguish it from its complementary.

The concept of purity as discussed above is also inapplicable, without resort to some artifice. Hence, the lower boundary of real colors is regarded as the locus of purples of highest purity, and the purple described above is found to have a purity of about 50 per cent.

Points A, B, and C indicate the trichromatic coefficients of the standard illuminants.

The *Y* tristimulus value is termed the brightness of the sample.

Thus, three parameters have been developed from which a color specification may be made. No two different colors can have the same values for these three parameters. Also they correspond closely to the Munsell notation—brightness comparing to value, dominant wavelength to hue, and purity to chroma.

## Applications

One purpose of such a specification is to describe the limits within which a color will be acceptable to either the manufacturer or purchaser. Such a method has become an important factor in modern production, where in some cases different parts of the same end-product are made by different manufacturers. Tolerances established from such specifications should be such that in the controlled production the discard from final inspection is not excessive. They must represent, actually, a compromise between the consumer's desire and the cost of manufacture. Examples of color tolerances are shown in Figs. 4, 5, and 6.

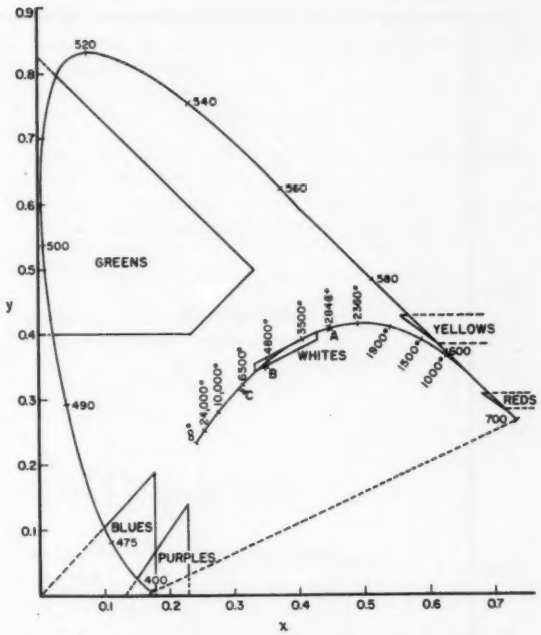


FIG. 4. RAILWAY SIGNAL COLORS AND PLANCKIAN LOCUS

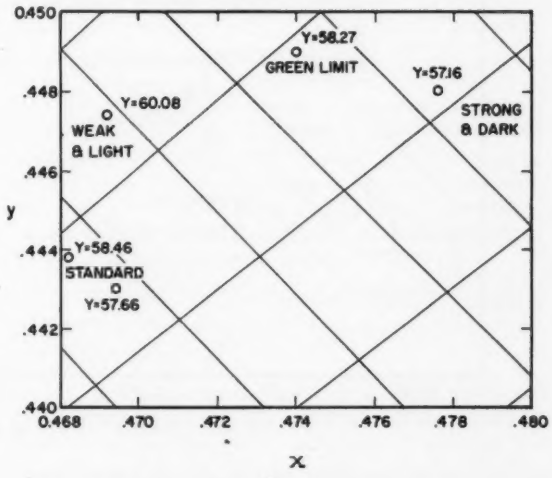


FIG. 5. STANDARDS AND TOLERANCES FOR A CARTON YELLOW

Figure 4 shows the permissible areas for railroad signal colors obtained with glass filters according to the AAR Signal Section specification 69-40.[2] The color areas are seen to be bounded by straight lines, expressed in terms of *x*, *y*, and *z*, which form the tolerances. The curved line within the chromaticity

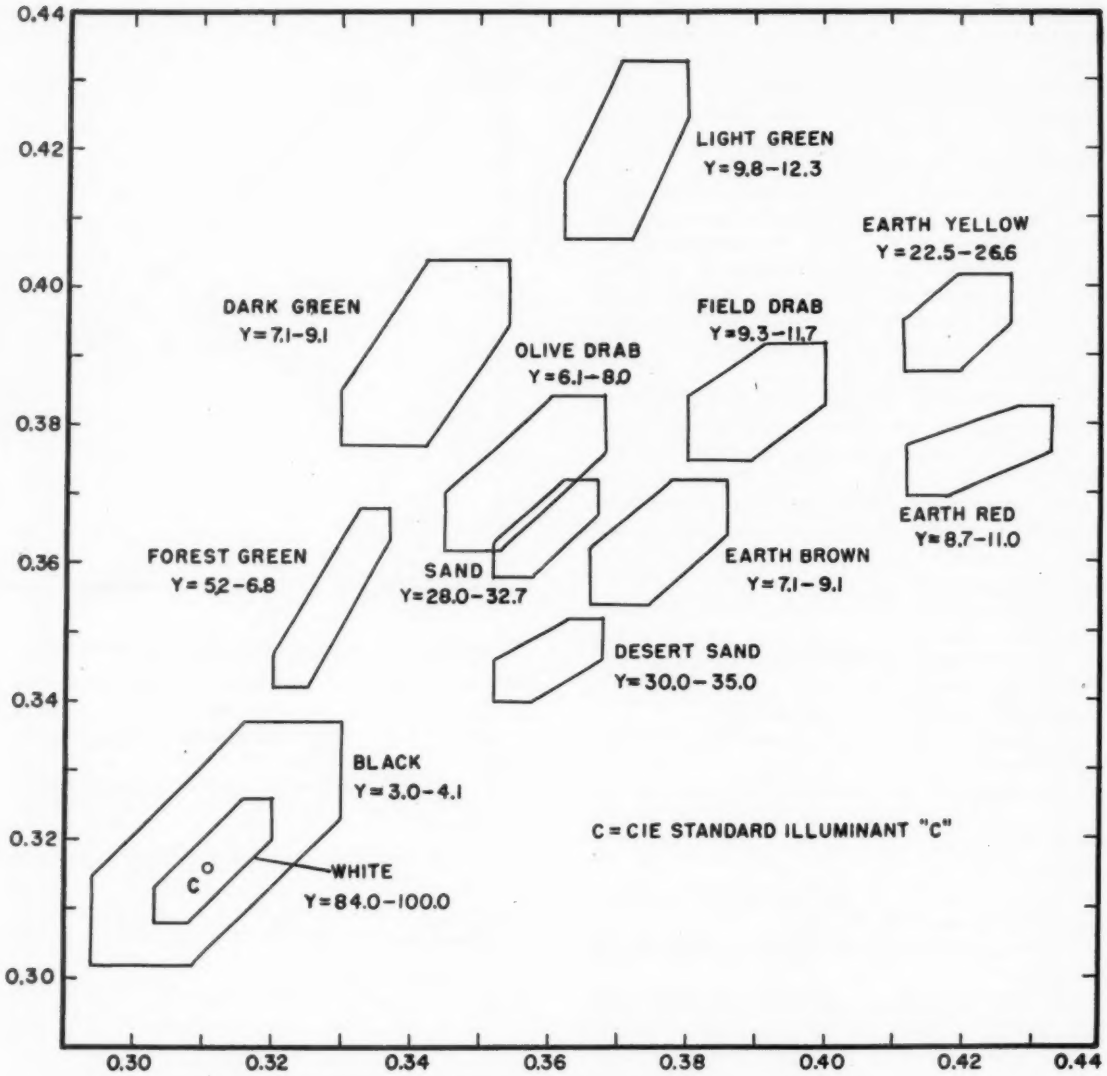


FIG. 6. CHROMATICITY DIAGRAM FOR COLORS OF CAMOUFLAGE CLOTH

diagram is the so-called Planckian Locus of various color temperatures of an incandescent solid.

Figure 5 is a specification for a colored paper used for packaging.[3] The points shown represent tolerance colors visually selected and transformed to CIE specifications. It will be noted that the tolerance colors are skewed about the standard color rather than symmetrically distributed. This is due, of course, to the visual selection which was made with respect to personal preference rather than from colors equally different from the standard. The lines with positive slope indicate dominant wavelength, and those with negative slope represent purity. Brightness values are given for the standard and limits.

Figure 6 shows the U. S. Government specification for camouflage nettings (MIL-C-765 A) and is an excellent example of the application of the CIE method for acceptable color production.[3]

The CIE method delineated above becomes rather cumbersome for control purposes unless some instrument such as a recording spectrophotometer with an automatic tristimulus integrator is used. Once a specification is derived by this method, however, other instruments such as filter photometers can be used

and their results translated to the CIE base or something similar.

Use of the method of numerical specifications may be expected to give the following advantages:

1. The need for trained color matchers becomes unnecessary, thus effecting considerable savings over a very short period of time, certainly enough to cover the cost of the equipment needed.

2. The problem of color standards changing with age is eliminated, since a permanent record of the color has been obtained by physical means, and future production can be compared to its values, rather than to the sample itself.

3. The data usually indicate the way in which a color must be altered to conform to the standard.

4. The method of specification applies equally well to all types of materials, whether solid or liquid, transparent or opaque.


**REFERENCES**

1. Judd, D. B., *Color in Business, Science and Industry*, John Wiley & Sons, New York, 1952.
2. Gibson, K. S., Haupt, G. W., and Keegan, H. J., "Specification of Railroad Signal Colors and Glasses," *Jour. Res. Nat. Bur. Stds.* 36 (1) 1 (1946); RP 1688.
3. Smith, Daniel, "On the Specification of Color Differences in CIE Coordinates." A paper presented at a meeting of Committee E-12 on Appearance, A.S.T.M., Cleveland, Ohio, March 5-6, 1952.
4. Hardy, A. C., *Handbook of Colorimetry*, Technology Press, Cambridge, Mass., 1936.


# Engineering Research Dividends

**Recent theses for advanced degrees, which were submitted as reports on Engineering Experiment Station research projects, will regularly appear in abstract form in *The Trend*. Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station.**

HAHN, E. J., "Large Deflection of a Tapered Cantilever Beam Loaded at Free End." M.S. in Aeronautical Engineering, 1953.

Large deflections of a tapered cantilever beam, subjected to a concentrated load at the free end, are examined both theoretically and experimentally. Calculated deflections, based on asymptotic approximation to the exact non-linear differential equation of bending, are shown to be in good agreement with experimental data. Ratios of tip deflection to beam length approaching 1/2 are considered.

Detailed results are presented for the following beam: length = 50 inches; width at clamped end = 8 inches; width at free end = 0 (approximately); constant thickness = 0.245 inches; material = 24ST aluminum alloy. The maximum load applied at the tip is 50 pounds. This yields the following results: (*a*) experimental tip deflection = 21.49 inches, (*b*) asymptotic series (two terms) tip deflection = 22.58 inches, (*c*) linear theory tip deflection = 29.90 inches. Error in using linear theory is 39 per cent, while only two terms of the asymptotic series result in an error of less than 5 per cent. Data at other points along the beam are also presented. In some cases, errors exceed those noted above for the tip values.

This investigation represents an extension of previous work by R. B. Trefny.* Trefny showed that an asymptotic series could be used to calculate large deflections of a uniform cantilever beam by comparing his results with exact data. In this present investigation a solution is offered for the heretofore unsolved problem of the tapered cantilever.

HATTRUP, J. S., "Further Investigation of Lateral Buckling of Rolled Steel Beams." M.S. in Civil Engineering, 1953.

The series of tests reported in this thesis on laterally unsupported rolled steel beams to determine their buckling strengths, tentatively concludes the experimental work of this project. Four 10LB15 beams with a semi-rigid end connection were tested, all with a span length of 90 inches. Two types of end connections were used: a top-and-seat-angle arrangement and a web-angle connection similar to the standard beam connections listed in the AISC Manual. Duplicate beams were tested with both types of end connections. Span lengths previously tested were 120, 180, 240, and 360 inches.

* Trefny, R. B., "Asymptotic Approximation to the Non-Linear Behavior of Beams," thesis for M.S. in Aeronautical Engineering, 1952. For summary see *The Trend in Engineering*, Vol. 4, No. 2 (April, 1952), p. 30.

Six lateral buckling tests were made on 10LB15 rolled steel beams simply supported in the plan and in the side elevation views, with torsional restraint at the span ends to prevent tipping about the longitudinal axis. Duplicate beams of span lengths of 60, 90, and 120 inches were tested. This series of tests augmented a previous series of tests with beams simply supported using sections of 18WF50, 12WF27, and 10125.4.

The loading was the same for all the tests and consisted of two equal loads at the quarter-points applied vertically on the top flange.

The experimental strengths were compared to those obtained by theoretical analysis using elastic theory. These tests seem to indicate that beams with an $Ld/bt$ ratio greater than about 1200 do not yield appreciably prior to buckling, and thus experimental and theoretical strengths agreed quite well. Beams with an $Ld/bt$ ratio of less than 1200 yielded prior to buckling, and the experimental strength was less than the theoretical strength for decreasing $Ld/bt$ ratio.

HARSHMAN, D. G., "A Study of the Effects of Tranverse Impact Upon Steel Tension Members." M.S. in Mechanical Engineering, 1953.

This thesis was the outgrowth of work reported in the M.S. thesis of H. L. Harrison (1950), "A Study of the Holt Method of Heat Straightening."* Its purpose was to determine more definitely the variables involved in the technique of straightening structural members in place by peening, and to ascertain their relative effect in causing permanent deformation. Since results of previous impact peening tests by hand were very susceptible to error, an impact-loading device was designed which fulfilled the following requirements:

1. The impact head had to be a freely falling body.
2. The rate of application of load had to be consistent and reproducible on successive tests.
3. The impact blows had to be distributed evenly along the test section.
4. The impact head had to hit the specimen as flatly as possible.
5. The blows had to be counted as applied.

Both the impact-tested and untested portions of the specimens were hardness tested. The fact that results under approximately the same conditions of testing were apparently irreproducible, shows that one or more unknown variables do exist. The large variation in deformation versus number of blows, that temperature difference cannot explain, may relate to grain-size variation.

* See also Engineering Experiment Station Reprints No. 49, "Effects of Light Peening on the Yielding of Steel," by H. L. Harrison and B. D. Mills, Jr., and No. 68, "Straightening Structural Members in Place," by H. L. Harrison.

MORRIS, J. A., JR., "A Heat Pump for Sewage Digester Plants." M.S. in Electrical Engineering, 1953.

A small sewage disposal plant, to serve the State Medical Institution at Lakeland Village near Lake Washington, has been designed for using a heat pump to supply the heat for digesting the so-called solid portion of the sewage. Instead of using electric heating for this purpose as was initially proposed, a small amount of electrical energy is used to operate a refrigerating unit which absorbs the heat from the incoming sewage and by compression raises the temperature of the refrigerant to such a degree as to transfer the original heat, plus a major portion of that from the electrical energy, to the digester vat. The tests described in this thesis indicate that the process is proving satisfactory, requiring only an average of 75 to 80 kwh of electric energy per day. Because of a lack of accurate heat-transfer data when the plates for absorbing the sewage heat were designed, the area of this evaporater surface may need to be increased, and a slightly larger motor may also be necessary for satisfactory operation during the coldest part of the year. Otherwise, the equipment seems entirely adequate.

The use of the heat pump in this field appears to be favorable in small plants in which the amount of gas from the digester is too small to be economically used as fuel, and where electric energy for heating would not cost more than two times as much as oil. On the other hand, it might prove even more favorable in large plants located in areas where electric energy is relatively expensive. In this case, all the digester gas could be used to generate electric energy for plant use or for resale. About 50 per cent of the original heat of the gas could be salvaged from the gas engine exhaust and cylinder cooling for use in digester heating. Any additional digester heat needed could be furnished by pumping heat from the incoming sewage by means of a heat pump operated by either a motor or gas engine. This would utilize from 70 to 80 per cent of the original heat of the gas in contrast to 20 to 30 per cent usually realized in generating electric energy by means of a gas engine-generator set.

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## SEWAGE WORKS SCHOOL TO BE HELD

The Fourth Sewage Works School will be held at More Hall, April 15-16 under the sponsorship of the Department of Civil Engineering, the State Department of Health, the Pollution Control Commission, the Association of Washington Cities and Office of Lectures and Short Conferences. The three consecutive courses are planned for plant operators and administrative personnel of sewage-treatment plants. Registration fee is $2.00.

# *Notes and Comments*

## UNIVERSITY ENGINEERS APPEAR ON N.W. SCIENTIFIC ASSOCIATION PROGRAM

Faculty members and research assistants of the College of Engineering took a prominent part in the program of the Engineering Section when the Northwest Scientific Association met December 29-30, at Spokane, Washington.

From the Department of Chemical Engineering, papers were presented by G. A. Kennar on "Gasification of Washington Coal," and by K. L. Mai on "Radioactive Tracer Techniques applied to Vapor-Liquid Equilibrium Measurements." Both men held EES fellowships. Professor J. H. Fisher, who presented "The Electromagnetic Flowmeter," and D. D. Hansen on "Brilliance Control of Neon Signs and Lighting" represented the Department of Electrical Engineering. Professor W. A. Snyder, of Mechanical Engineering, spoke on "Olivine Flour in Foundry Surfaces."

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## NEW RESEARCH PROJECTS

**Project No. 153. Effect of Elevated Pressure on Catalytic Cracking Mechanism.** L. N. Johanson, Assistant Professor of Chemical Engineering, Supervisor; F. C. Franklin, Research Assistant.

**Project No. 154. Extended Network Analyzer Studies.** L. J. Lewis, Associate Professor of Electrical Engineering, Supervisor; A. Ishimaru, Research Assistant.

**Project No. 155. Corrosion Rates of Single Crystals of Metals.** A. L. Babb, Assistant Professor of Chemical Engineering, Supervisor; I. K. Arora, Research Assistant.

**Project No. 156. Coal Gasification.** R. W. Moulton, Professor of Chemical Engineering, Supervisor; G. A. Kennar, Research Assistant.

**Project No. 157. Mechanical Language Translator.** T. M. Stout, Assistant Professor of Electrical Engineering, Supervisor; R. S. Waggoner, Research Assistant.

**Project No. 158. X-Ray Studies of Ceramic Materials.** J. I. Mueller, Associate Professor of Ceramic Engineering, Supervisor; B.S.R. Sastry, Research Assistant.

**Project No. 159. Seepage Past Dams by Electric Analogy.** R. G. Hennes, Professor of Civil Engineering, Supervisor; F. W. Opsal, Research Assistant.

**Project No. 160. Adsorption of Hydrocarbons on Activated Charcoal.** R. W. Moulton, Professor of Chemical Engineering, Supervisor; F. Ore, Research Assistant.

**Project No. 161. Design of Ozonation Applicator System for Water Sterilization.** R. G. Tyler, Professor of Sanitary Engineering, Supervisor; D. F. Hogan, Research Assistant.

**Project No. 162. Polarization in the A. C. Electromagnetic Flowmeter.** J. H. Fisher, Assistant Professor of Electrical Engineering, Supervisor; M. C. Arya, Research Assistant.

**Project No. 163. Analysis of Built-up Structures.** D. Vasarhelyi, Assistant Professor of Civil Engineering, Supervisor; R. O. Knudson, Research Assistant.

**Project No. 164. Malad Subgrade Correlation.** R. G. Hennes, Professor of Civil Engineering, Supervisor; A. N. Corthell, Research Assistant.

**Project No. 165. Diffusion Studies in Liquids.** A. L. Babb, Assistant Professor of Chemical Engineering, Supervisor; G. L. Otterbein, Research Assistant.

**Project No. 166. Beam Column Joints and Plane Buildinc Frames.** R. A. Hechtman, Professor of Structural Research, Supervisor; Y. Y. Hsieh, Research Assistant.

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## ENGINEERS IN THE NEWS

**J. L. McCARTHY,** Professor of Chemical Engineering, read a paper on "Vapor-Liquid Equilibria in the System $NH_3$ - $SO_2$ - $H_2O$ Determined by the Radioactive Tracer Method," at the meeting of TAPPI in New York, February 16. Co-authors were Research Assistant **D. T. HAYDEN** and Assistant Professor **A. L. BABB,** of the Department of Chemical Engineering. Dr. McCarthy also addressed the Cellulose Discussion Group at Wilmington, Delaware, on "Some Aspects in the Chemistry of Lignin."

**G. H. KEITEL,** co-author of the article on VHF field strength in this issue of *The Trend,* is continuing his studies toward a Ph.D. in Electrical Engineering at Stanford University.

**R. N. KUSIAN,** Director of the Environmental Research Laboratory, will present a paper on "Planning a State-Wide Air-Pollution Advisory Service" at the meeting of the National Air Pollution Control Association to be held at Chattanooga, May 3-5. The

Environmental Research Laboratory will also arrange a display of specially designed instruments for industrial hygiene and air-pollution measurements at the Symposium on Instrumentation for Industrial Hygiene at Ann Arbor, May 24-27.

**H. C. MARTIN,** Professor of Aeronautical Engineering, attended the meeting of the Institute of Aeronautical Sciences in New York, January 28, where he led a discussion of the paper "Stiffness and Deflection Analysis of Complex Structures," which was presented by **M. J. TURNER** of Boeing. The paper reported a joint investigation by Dr. Martin, Mr. Turner, and Professor **R. W. CLOUGH** of the University of California.

At the meeting of the American Foundrymen's Society in Cleveland, May 13, **W. A. SNYDER,** Assistant Professor of Mechanical Engineering, will present a paper on "Olivine-Silica Molding Sands," of which Professor **G. A. SCHALLER** of the same department is co-author.

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# Sixth Annual Pacific Northwest Industrial Waste Conference

SINCE 1949, A CONFERENCE ON INDUSTRIAL WASTES has been held each year in the Pacific Northwest. This year, the Conference was held at the University of Washington, on March 18, and 19, sponsored by the departments of Civil Engineering and Chemical Engineering, the Engineering Experiment Station, the Environmental Research Laboratory, and the Office of Short Courses and Conferences. The purpose of these conferences is to permit a free exchange of ideas, experiences, and problems on industrial wastes. Emphasis is on methods of conservation or waste utilization, waste prevention, and better processing methods, rather than on methods of waste treatment prior to their discharge in the waterways or in the atmosphere. Registrants numbered 154. The majority of those in attendance were from industry. Others were engineers, chemists, and planners from local, state and federal governmental agencies and from private professional pursuits.

Tremendous strides have been made by industry in abating water and air pollution and in utilizing or reducing what had formerly been wasted through the industrial sewer or through the industrial stack. Much still remains to be accomplished if our waterways and atmosphere are to be kept in a satisfactory condition and not allowed to deteriorate to where they are a detriment to all concerned. Some industries are loathe to discuss their problems or even to tell how they have corrected previous detrimental waste discharges. They feel that the less the subject is discussed, the better will be their public relations. Fortunately, fewer and fewer industries are maintaining this attitude. In fact many of the large industries are taking the lead and are providing the impetus for research and correction of industrial waste discharges. Educational institutions, for their part, are providing opportunities for public discussion of industrial waste problems.

***Technical Sessions.*** These were divided into four categories: general and air pollutions, wood industries, food industries, and chemical industries. The interest of those in attendance seemed about equally divided among the different categories.

A panel on "Water Quality Requirements for Industry; Municipalities; Agriculture; Fisheries; and Recreation" set the background for goals to be attained in waste disposal by water dispersal. Fred Merryfield, Professor of Sanitary Engineering at Oregon State College, explained how some industrial water quality requirements exceed those for human consumption, while other industries are concerned very little with water quality for their processing. Jerry Allen, Seattle Assistant Water Superintendent, stated that the ideal municipal water supply is sparkling clear, pleasant to the taste, temperature reasonably cool, neither corrosive nor scale-forming, free from organisms capable of producing infection. Warren Leatham, Agricultural Engineer, Bureau of Indian Affairs, explained how, under controlled conditions, paper pulping and cannery wastes have been successfully applied to land for gaining an increase in crop growth due to their moisture and chemical constituents which the soil needed. Donald R. Johnson, Washington Department of Fisheries, stated that this is a critical time in the development of our state and that now we must pay attention to the maintenance of our water resources for *all* uses, so that they may be used likewise by posterity. Robert E. Leaver, Washington Department of Health, stressed the aesthetic considerations in water quality for recreation, as well as the toxic and bacterial substances that may result from waste discharges.

Air-pollution problems created by the dispersal of industry were discussed by William E. Rand, Director of Research, Stanford University. He pointed out how we have numerous governmental agencies that are concerned with the food we eat, the water we drink, but that scarcely any are concerned with the air we breathe.

According to E. F. Kurth, Research Chemist Chief at the Oregon Forest Products Laboratory, about 2.5 million tons of Douglas-fir bark alone is available

**Speakers at the first session of the Conference on Industrial Waste.** *Left to right:* **Fred Merryfield, Professor of Sanitary Engineering, O.S.C.; E. J. Allen, Ass't Water Sup't, City of Seattle; R. E. Leaver, Sr. Public Health Engineer, W.S.D.H; W. J. Leatham, Area Agricultural Engineer, U.S.D.I., Portland; F. J. Dohrer, consulting engineer, Seattle; J. L. McCarthy, Professor of Chemical Engineering, U. of W; W. E. Rand, Director of Research, Stanford Research Institute. D. R. Johnson, Supervisor of Research, Washington State Department of Fisheries, is not shown in the photograph.**

annually in Oregon and Washington for extraction of waxes, numerous chemicals, and for use in hard boards. Very little use of this bark is now being made except for heat production by burning. Sawmill residues are finding widespread use as mulches by orchardists, growers of small fruit, and nurserymen. James H. Hall, Crown-Zellerbach Corporation, described the new ammonia base sulfite pulping and recovery system in use at their Lebanon plant, a process which is materially reducing stream pollution and permitting the recovery of pulping chemicals. Warren Eldridge, chemist, described tests for toxicity to aquatic life, as conducted at the Deception Pass Marine Biological Station. While some waste discharges will not kill the fish, they kill their food organisms and thus indirectly affect fish survival.

Other papers at the Conference dealt with the disposal, and utilization of radioactive materials; methods of handling cannery, milk processing, sugar beet, and slaughterhouse residues to reduce waste discharges and recover by-products; reduction of air pollution at gas works, pulp mills, aluminum plants, etc.; planning of industrial dispersion and its waste problems; composting organic wastes for humus and fertilizer recovery, and how municipalities should handle industrial discharges to their sewer systems.

A very interesting session demonstrated the dispersion and oscillation of wastes by tidal action in inland water. Prof. R. G. Tyler used a scale model of Puget Sound built by the University's Oceanography Department.

ROBERT O. SYLVESTER

## MOTOR MAINTENANCE CONFERENCE

The Third Annual Motor Vehicle Maintenance Conference was held at More Hall, March 22-24, sponsored by the Engineering College in cooperation with the Washington Automobile Club, Northwest Section of the SAE, Seattle Chapter, National Association of Fleet Supervisors, Seattle Safety Council, Washington Motor Coach Association, and Washington Motor Transport Association. Over 220 registrants were listed, including fleet superintendents, shop foremen, service engineers, senior mechanics, owners, and others concerned with motor vehicle maintenance. Factory representatives from many states conducted two panels devoted to problems of heavy duty, and light and medium duty operators, respectively, while other panels discussed problems of the school bus, city delivery, and utilities operators. Special attention was given to preventive maintenance on all of the panels. An extensive display of manufacturer's cutaway models and other visual aids attracted considerable interest. In charge of the Conference were Director Fred H. Rhodes, Jr., Professor of Civil Engineering, and the MVMC Promotion Committee, John W. Pauli, chairman, Carl R. Seaburg, vice-chairman, and Lee Ketchum, secretary.

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### VARIATION OF VHF FIELD STRENGTH

*(Continued from page 14)*

obtained were 0.357, 0.376, and 0.230 for Seattle-Tacoma, Toledo, and Portland data, respectively. Figure 9 shows curves of average field strength and index for August, 1951. This does not match the excellent correlation obtained by Pickard and Stetson.

#### Conclusions

On the basis of the results on this study, as compared with those of Pickard and Stetson, the correlation between average field strength and the index of refraction at the ground level is a function of the particular path being studied and the point where the index is measured. As for the hourly correlation of field strength and the index, apparently there are too many unknown variables which will prevent good correlation.

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### CONFERENCE ON ROAD BUILDING

*(Continued from page 15)*

thickness was achieved by the consideration of both swell pressure and soil stability. From the Oregon Highway Department, Mr. Mack H. Astrup explained how modern techniques in planting and sodding have reduced the cost of maintaining roadside slopes.

On Thursday afternoon various elements of bituminous surfacing were analyzed. Mr. D. E. Stein, Washington Highway Department, described low cost surfacings. Professor Martin Ekse, University of Washington, told of research on the correlation of average surfacing requirements with average soil properties, on a regional basis. A convincing demonstration of the merit of existing design practices along the Pacific Coast was provided by Mr. Ernest Zube's report on his efforts to check laboratory tests against actual pavement performance in his capacity of Supervisor of Materials and Research Engineering for the California Division of Highways. The managing Engineer of the Pacific Coast Division, Asphalt Institute, Mr. Bernard A. Vallerga, closed the day's session with a well-illustrated comparison between good and bad practices in bituminous construction.

A feature of the meeting was the "Engineers' Notebook," Friday morning when half-a-dozen engineers gave brief talks on out-of-the-ordinary road problems from subversive beavers and helpful snow weasels, to wire fencing for the control of rock slides.

The engineering standards leading to the most advantageous use of timber in highway structures were developed in two papers by Mr. C. F. Craig of the Baxco Corporation, Portland, and Mr. Robert Eby of the Weyerhaeuser Sales Company.

The closing session of the Conference on Friday afternoon emphasized the transportation problem near and into metropolitan centers. Mr. Robert Lochow of the Portland Cement Association discussed the use of cement-treated bases for feeder roads, and Mr. P. N. Royal of the Seattle City Engineer's office presented a thorough discussion of the legal and financial problems involved in the improvement of city streets. The use and limitations of financing through the establishment of local improvement districts was explained. Finally, Mr. J. C. Young, Engineer of Design for the California Division of Highways, gave local engineers the benefit of California's experience with expressways and freeways. His talk involved many items of design and planning which were found to be important to the success of these impressive undertakings.

Next year's meeting will be held in Corvallis, Oregon.

**R. G. HENNES**

# PUBLICATIONS

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## BULLETINS

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58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
60. An Electromagnetic Balance for Force Measurement of Current Control. Fred Scoville Eastman. 29 pp. 1932.
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72. The Derivation of the Mean Temperature Difference Between a Saturated Gas and a Cooling Liquid, and also the Derivation of the Mean Velocity of Such Gas. Sybren Ruurd Tymstra. 19 pp. 1933.
74. The Deformation of Hard Grade Reinforcing Steel During and After Construction in a Reinforced Concrete Building. Sergius Ivan Sergev. 33 pp. 1933.
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116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part III, The Investigation of Models of the Original Tacoma Narrows Bridge Under the Action of Wind. F. B. Farquharson. 125 pp. 1952.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part IV, The Investigation of Models of the New Tacoma Narrows Bridge Under the Action of Wind. F. B. Farquharson. (In press.)
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part V, Extended Studies: Logarithmic Decrement, Field Damping, Prototype Predictions, Four Other Bridges. G. S. Vincent. (In preparation.)
117. Production of Wood Coke from Waste Wood. Warren L. Beuschlein. 40 pp. 1950.
118. Investigations in Aeronautics from the Department of Aeronautical Engineering. Edited by R. M. Rosenberg. 120 pp. 1951.
119. The Extremum Principles of the Mathematical Theory of Elasticity and Their Use in Stress Analysis. (The Walker-Ames lectures of the Spring Quarter, 1950.) W. Prager (Brown University). 30 pp. 1951.

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2. Iron and Steel Manufacture in Washington, Oregon. California, and Utah. Joseph Daniels. 69 pp. 1929.
3. Coal in Washington. Joseph Daniels. 17 pp. 1934.
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3. The Theory of Fractional Parts Developed for Structural Beam-Column Members Preceded by an Elementary Discussion of Simple Beam and Column Design. Sybren Ruurd Tymstra. 32 pp. 1943.
4. Gaging Chart for Horizontal Cylindrical Tanks with Flat Heads or with Convex Heads. Sybren Ruurd Tymstra. 4 pp. 1944.
5. Gaging Chart for Cylindrical Tanks with Different Types of Heads. Sybren Ruurd Tymstra. 7 pp. 1945.
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